THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOLUME XVIII

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ENGINEERS' DIGEST
REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVIII No. 1 JANUARY, 1957

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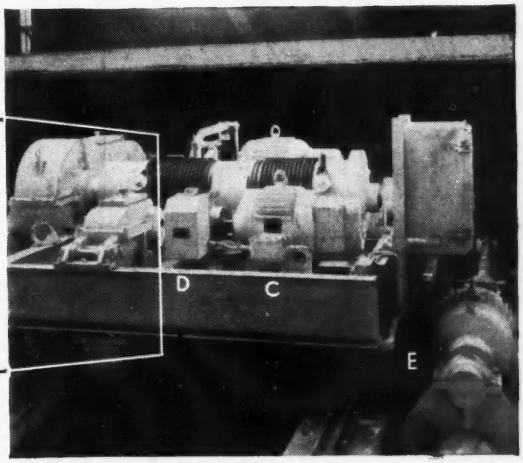
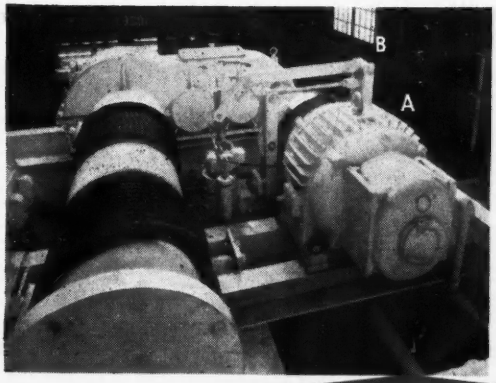


Metrovick equipment is well on top in this 10-ton Wharton overhead shop crane. The hoist is an 18-h.p. 720 r.p.m. M-V motor fitted with a thrustor-operated brake giving precise control with stable creeping speed on load. The need for inching is thus eliminated. Drives for the long travel and cross-traverse are M-V 10-h.p. 715 r.p.m. and 3-h.p. 700 r.p.m. type MZ slipring motors respectively. A 6-inch Perigrip brake operates on the cross traverse. Write for details of the range of M-V a.c. and d.c. motors, control gear and Perigrip electromagnetic brakes for crane drives.



In the illustration (left) A is the 18-h.p. 720 r.p.m. hoist motor fitted with Stacreep thrustor control B. The long-travel drive, motor E, is shown at the top of page. The 3 h.p. cross traverse motor is seen at C and the 6-inch Perigrip brake at D.

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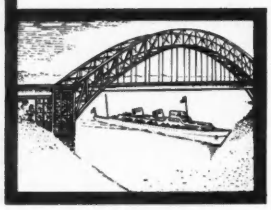

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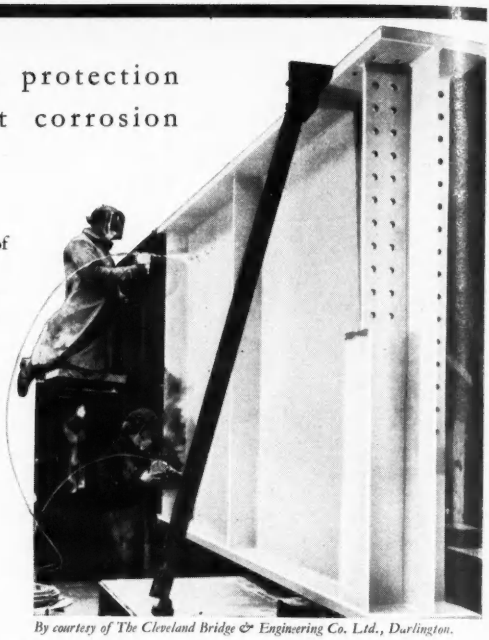

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *IMPROVING THE LIFE OF CUTTING TOOLS*

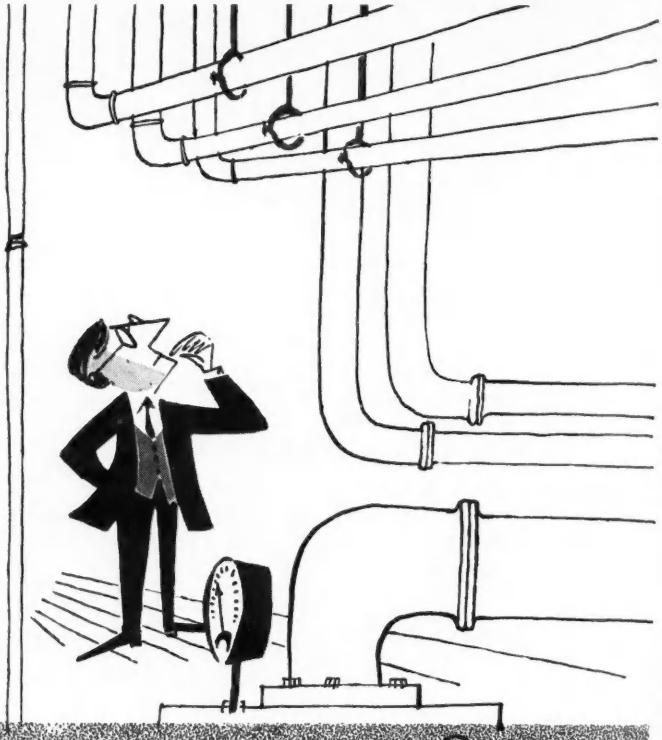
In a recently issued patent specification it is stated that the life of tools for cutting operations or for non-cutting deformation, such as drawing dies and forging dies, can be substantially increased by providing the working surface or cutting edge of the tool with a coating of a hard nitride, boride, and/or silicide of titanium deposited by a gas-phase reaction. It is claimed that coatings of this type can be applied both to steels and to other materials, e.g., bronzes, so that no special demand need be made on the parent material used with regard to wear. Coatings of titanium nitride, or titanium nitride and titanium carbide, differ from ordinary metal surfaces in their behaviour with respect to metallic sliding characteristics, in that they have no tendency to form alloys, and therefore do not tend to seize. The claim is made that working and cutting tools treated in accordance with the proposed method are particularly resistant to wear, since, during the cutting operation, the backing metal of the tool does not come into direct contact with the metal of the material to be machined. The coatings are, as stated above, applied by reaction from the gaseous phase. Titanium nitride coatings can be directly deposited on the surface of the workpiece, but, for producing coatings of titanium silicides, titanium is first deposited on the surface, and this is then converted into titanium silicide by gas-phase treatment. Coatings of the borides of titanium can also be produced, and it is possible to deposit mixed crystals of borides, nitrides, and silicides.

● *A METHOD OF ACCURATE LINEAR POSITIONING BY TRANSDUCERS*

A new type of transducer construction has been developed for the accurate linear positioning of parts. It was especially designed for application in machines in which cutting tools must be precisely positioned, and in this application it is claimed that the transducer can measure linear displacements to accuracies of 0·0001 in. over distances of several feet. The unit is made up of two electromagnetically coupled parts constituting a primary and a secondary. The transducer primary consists of a bifilar coil wound in two insulated spiral grooves cut in a long cylinder, the leads from the primary being connected to slip rings. The secondary also contains a bifilar coil, located on the inside of a sleeve which can slide over the primary. The primary and secondary coils can be physically aligned over each other to give maximum electromagnetic coupling. When the secondary is shifted so that its wires are midway between primary wires, the voltages induced in two adjacent primary-coil wires cancel one another but, if the secondary is shifted further in the same direction until the wires line up again, the induced primary voltage reaches a maximum of the opposite phase. The zero-voltage nulls, appearing between voltage peaks as the secondary sleeve is moved along, are used for the linear positioning. However, since the system is ambiguous, the transducer is employed only for fine positioning. In practice, a coarse servo-mechanism is used to position the machine slide to an accuracy of less than half the distance between transducer nulls. When this position is achieved, the fine system is used to adjust the position to the nearest null position.

● *NEW NICKEL-FREE STAINLESS STEEL*

A recent report points out that, although some of the low-nickel stainless steels, e.g., ferritic 17% chromium steel, have adequate corrosion resistance in mildly corrosive service, their mechanical properties do not permit extensive drawing and fabrication at room temperature. Austenitic stainless steels, such as 18% Cr/8% Ni and 17% Cr/7% Ni, have high percentages of nickel which permit cold-working and hot-forming operations ; however, many of the lower nickel steels contain sufficient delta-ferrite at hot-working temperatures to present rolling problems. It is suggested in the report that these and the shortness of nickel make the need for fully austenitic nickel-free steel evident. A new austenitic stainless steel has now been developed in which nickel is replaced by manganese and nitrogen, to give improved strength and satisfactory formability. The elevated-temperature tensile and yield strengths of the new material are reported to be higher than those for a number of comparison steels of conventional composition ; however, it should be borne in mind that the test data obtained refer to short-time tests only and therefore do not indicate any advantageous use of the new steel for prolonged periods at elevated temperature. The resistance of this nickel-free steel to intergranular corrosion in oxidizing and reducing



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acids was investigated, and it was found that, in boiling 5% nitric acid, the new material is comparable with a 16% Cr/1% Ni/17% Mn steel. It is claimed that, because of its high yield strength in both the annealed and cold-worked condition, the new steel permits weight reduction in a number of applications. The material may be deep-drawn, but the high yield strength requires increased die pressures.

● *MOUNTING OF JET-ENGINE VANES WITHOUT PUNCHING SLOTS*

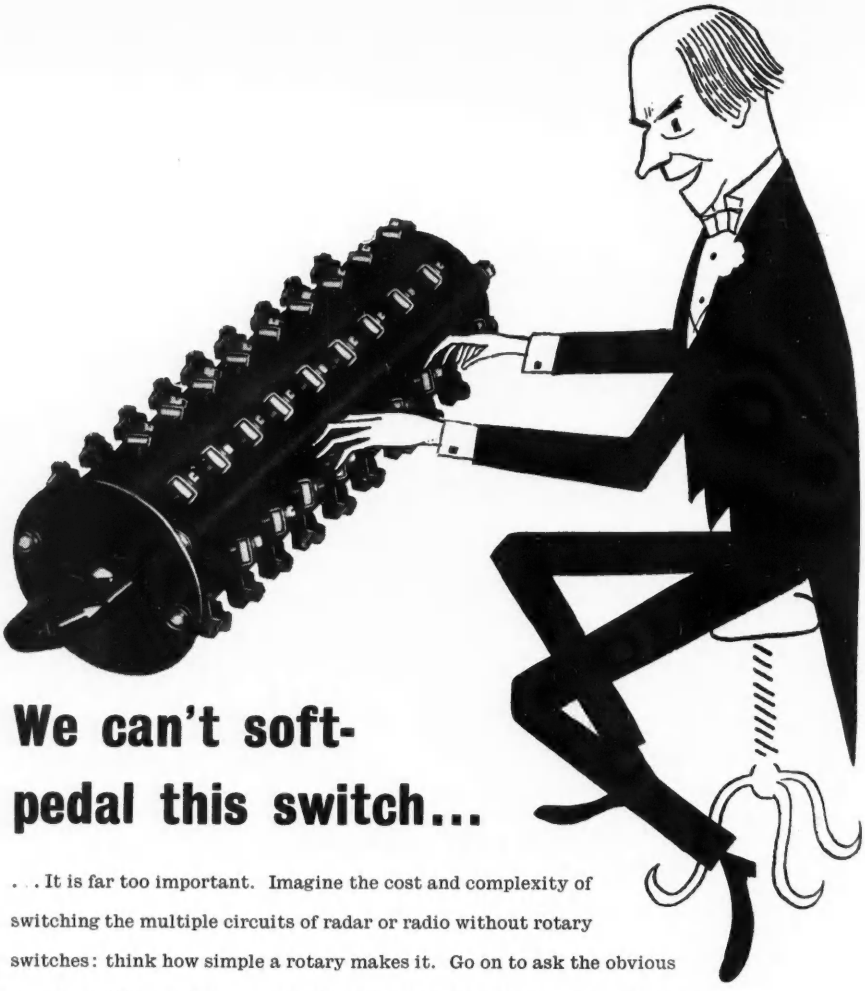
Until recently, jet-engine vanes were most satisfactorily mounted in their metal shrouds by first punching a slot in the shroud and then inserting the vane. It is reported that after five years of development it is now possible, by means of a special vane-piercing machine, to fit the vanes into the shroud without punching the slot. This method is said to be in successful use at the works of a prominent jet-engine manufacturer. With the machine used, in a single operation, the vane is driven at a velocity of six inches per second by a force of four tons into the inner circumference of the shroud. Instead of the conventional prepunched method, the new machine makes the use of tolerances almost non-existent. The hydraulically operated machine was put into trial operation for two years, during which time it underwent constant modification. It was then put into production on a part-time basis with enough success to warrant the installation of a number of additional machines. The main stabbing operation is performed horizontally. After a circular shroud has been positioned, the stabbing is performed radially from the centre of the shroud. Vanes are fed from a vertical magazine into a shuttle and successively rammed home into the skin making up the perimeter of the shroud. In a later step the vanes are driven through a second skin overlaying the first.

● *ACOUSTIC-WAVE PRODUCER AS A POWER GENERATOR*

It is well known that, by the application of heat to one part of a confined column of gas, vapour, or liquid, the fluid column may be set vibrating longitudinally. Proposals have been made to convert vibration energy into electrical energy by way of a transducer and to utilize this electrical energy, for example, to supply bias voltage and currents for the operation of amplifiers or other components of unattended telephone repeater stations. A recent invention proposes to improve the efficiency of such an acoustic-wave producer by incorporating a pair of closely spaced heat exchangers, one heated and the other cooled. It is claimed that with such a device oscillations of large amplitude can be produced. If the device is made in the shape of an open-ended tube, loud sounds can be produced, and these may serve as a fog-horn or alarm. Where an electrical output is to be produced, the tube is fitted with a transducer, applied at an appropriate point on the tube. It is stated that this device is also applicable in the form of a heat engine of the two-phase type, i.e., having a liquid and a vapour phase. In such an apparatus the vapour phase is caused to expand and contract, owing to alternate vaporization of a small fraction of the liquid and its subsequent condensation. These expansions and contractions serve to move a portion of the liquid in bulk, and this movement can then be converted into reciprocating or rotary motion by an appropriate mechanism. By fitting a cooling element in the form of a heat exchanger in the optimum position relative to the point at which heat is applied, it is claimed that improved performance can be obtained, though the power output of such a device will be small.

● *METALLIC MUFFLE FOR SINTERING STAINLESS STEEL*

The application of powder-metallurgy techniques to the production of stainless-steel parts involves many problems, one of the prime considerations in this type of fabrication being the type of furnace muffle to be used. It is necessary that the muffle should withstand temperatures in the range of 1300 to 1350°C and also the thermal shock resulting from stoking the sintering boat through the furnace. Refractories such as alumina, mullite, sillimanite, etc., meet temperature requirements, but the thermal-shock properties of these materials are frequently inadequate. In a closed system, cracks in a muffle cannot be tolerated, since air leakage will contaminate the atmosphere. In the case of hydrogen or other reducing atmospheres, this will result in a lowering of the dew point—an intolerable condition, in view of the extremely dry atmosphere required for sintering stainless-steel parts. It is evident, then, that any muffle for this type of service should have good thermal-shock characteristics. Most ceramics do not meet this requirement, and the few ceramics which might prove satisfactory are not available in the dimensions required. In view of this difficulty, an investigation was made of metallic muffles made from alloys with high melting points and it is reported that muffles fabricated of Inconel have proved successful. It is stated that, although this material is being used at a temperature close to its melting point (1395°C), very little creep or sag was noticeable after months of operation. Gas-tight seals were made for each end of the muffle, to ensure leak-proof connections between muffle and cooling chambers. Although a round muffle was used in this particular case, other shapes have been employed.



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● *VIBRATORY OIL-WELL DRILLING*

The increasing depth to which oil wells must nowadays be drilled makes the efficiency of drilling equipment a matter of great importance. Currently, most wells are drilled by rotary drilling, but an investigation is now in progress which aims at the application of sonic vibration techniques to drilling operations. A recently made basic study of rock drilling shows that penetration of a rock bit depends primarily upon the rate at which mechanical energy can be delivered to the rock per unit area of base hole. Present research therefore aims at delivering more mechanical energy to the rock by vibrating the bit at frequencies of the order of hundreds of cycles per second. Initial experiments conducted on a laboratory scale have proved that most effective drilling results are obtained by mounting a bit on one end of a longitudinally vibrating bar and forcing the end against the rock, the vibration in the steel column being created by a magnetostriction transducer. Development work is now concentrated on the perfection of a transducer for deep-well drilling, designed to vibrate a 10½-in. diameter bit at a frequency of about 300 cps and to follow this bit down the hole. The transducer itself is about 25 ft in length and, when fully excited, should develop about 100 hp. The transducer is mounted in the drill string between the bit and the drill collar. A filter isolates the vibration of the transducer from the rest of the drill string, and power for the transducer is transmitted through an electrical conduit which is mounted concentrically in the drill string, the latter being rotated in the same manner as for conventional rotary drilling. Experience with previous transducer models indicates that the combination of vibration and rotation of the bit should result in rates of penetration about double those obtainable with rotation alone.

● *TREATING METAL MELTS BY PULSATING ELECTROMAGNETIC FIELDS*

Several methods exist in which molten metal is exposed to electromagnetic fields, and the use of ultrasonic vibrations has also been proposed as a means of influencing the structure of the metal during solidification. A recent invention describes a method of casting metals, in which use is made of a pulsating electromagnetic field of force produced by a pulse generator, which causes impulsive movements of the melt. In order to carry out the process, which is claimed to have proved successful for continuous casting, a coil is placed around the molten metal, and through this coil an electric current passes during the discharge period of the pulse generator. It is stated that the effect obtained by this means is so great that even low energies produce movement in the surface of the molten metal. The windings surrounding the molten metal can be so adjusted that the greater portion of the total number of turns extends above the level of the molten metal; alternatively, all or most of them may lie below this level. In the first case the pressure exerted by the particles of the molten metal upon the particles below is reduced by the electromagnetic field, which acts in opposition to the force of gravity, while in the latter case the total force of all the particles is increased by the magnetic field, which directs the particles towards the centre of the coil. It is stated that, in both cases, the short pulsating action of the magnetic field effects an axial movement of the molten metal, caused by the change of pressure inside the molten mass. This movement is said to have a favourable influence on both degasification and stratification of particles, so that a homogeneous compact texture of the metal is obtained. The molten metal may also be degasified by an intermittent rotating field, the direction of rotation being changed repeatedly.

● *HEAT-TREATING PRECISION PARTS*

It is reported that in the manufacture of small precision steel parts for instruments and other purposes the parts can now be finish-machined prior to heat-treating, as the result of a new heat-treating process which has recently been developed. It is claimed that the new process permits heat treatment of even the smallest stainless-steel parts to any desired degree of hardness or toughness without causing discoloration of surface finish or any dimensional distortion. The process is said to be applicable to all hardenable grades of stainless steel, and will produce both toughness and hardness of any desired degree all the way through the metal. The original research was done as an outgrowth of work on heat-treating small stainless-steel watch parts. The new process is achieved by precise control of the heat-treating atmosphere through special preparation of the atmosphere gases. Dry hydrogen or dissociated ammonia with a dew point under — 60°F is used in the furnace for bright-hardening, and vacuum for high-temperature tempering. Dry hydrogen is used for annealing and vacuum is used for batch assembly. Not only does this process prevent distortion of the minute parts but it can also be arranged to produce controlled growth or shrinkage in their dimensions. The usefulness of this versatility has been demonstrated by restoring to correct size a batch of dimensional reject parts. The principal advantage of this process is that finish-machining may be effected before heat-treating, while the material is still in the soft state. It also eliminates final machining and such operations as cleaning and polishing the part after the material is hardened.

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● *EXPLOSION OF TITANIUM DUE TO FUMING NITRIC ACID*

Titanium alloys are ideal structural materials for chemical and liquid rocket-engine systems using fuming nitric acid, because of their light weight, good mechanical properties, and excellent corrosion resistance. Unfortunately, several serious accidents have occurred as the result of the violent reaction of commercial alloys with fuming nitric acid. Titanium-base alloys could not therefore be considered reliable for contacting with fuming nitric acid until this phenomenon was explained. In order to provide information as to the scope of the problem and the significance of the possible variables causing the pyrophoric reaction, an investigation was carried out under laboratory conditions. In these tests the pyrophoric reaction obtained was positive and emphatic, a brilliant flash of flame being accompanied by a loud report and scattering of acid and glass fragments of the test vessel from the extreme heat and rate of reaction. It was found that fuming nitric acid with less than 1·34% water and more than 6% NO_2 is capable of sensitizing titanium-base alloys, causing violent pyrophoric reactions initiated by shock or other means of excitation, and that titanium exhibits corrosion prior to the pyrophoric reaction. It is believed possible that the reaction may be due to a deterioration of the passive film of inherently corrosion-resistant titanium, or to pentration of the film by ions produced through dissociation of nitric acid resulting from a lower water content. Upon breakdown of the film, the nitric acid is then capable of attacking the reactive titanium ions, especially when the metal is stressed. As the attack becomes intergranular, finely divided separate grains of titanium metal are produced. Application of a suitable energy threshold is then capable of detonating an explosive mixture of an actively reducing metal in the presence of a strong oxidizing medium.

● *IMPROVED HILSCH VORTEX TUBE*

A recent patent specification provides evidence of continued efforts to improve the operating characteristics of the Hilsch vortex tube so that it can be used as a cooling device. The proposed improvement consists of cooling the tube along that part of its length where heat separation occurs by means of a stream of liquid cooling medium sweeping the external wall of the tube. This proposal is made in cognizance of the fact that there exists a very great transfer of heat from the gas to the wall of the tube, assuming that the flow in the tube is not disturbed. It is suggested that the cooling jacket provided for this purpose should preferably be extended over the whole length of the tube. The inlet for the cooling medium will usually be provided, at or near the point of the vortex tube at which, in the absence of cooling, the hotter gas attains its maximum temperature. Alternatively, the tube may be cooled on its inner surface by means of a coolant flowing along the inner wall of the vortex tube; in this case the coolant inlet will be located near the gas inlet. The beneficial effect of the provision of such a cooling jacket is illustrated by an example in which 30 kg of air at approximately 22°C were introduced at a pressure of 5·5 atm into a vortex tube of 10 mm internal diameter and 190 mm length between diaphragm and throttle valve. By means of a cooling jacket the vortex tube was intensely cooled with water at approximately 10°C. The entire quantity of air was discharged from the tube as colder gas, when the throttle valve was closed, at a temperature of —14°C. Without cooling, the gas discharge temperature would be nearly equal to the inlet temperature of 22°C.

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VOL. XVIII No. 1 JANUARY, 1957

The "Multiplex" Electric Railway System

By Olov Åkerman, B.A., B.Sc.*

In conventional trains intended for long-distance traffic, using one single-phase a.c. electric locomotive, tractive power is concentrated entirely on the axles of the locomotive only and, as a rule, no electric braking is incorporated. On the other hand, in modern d.c. underground trains, every axle can be electrically driven and braked. Thus, since both starting and braking power is effected by a multiplicity of electric motors, mechanical wear and tear on coaches and tracks is low, with a corresponding reduction in maintenance, while the safety of passengers is greatly increased by virtue of the double braking feature provided. Furthermore, with the electric-motor brake (as distinct from the mechanical brake, with its disadvantage of wear), electrical braking power can actually be utilized for other useful purposes, e.g., for feeding the electrical heating system of the train.

An additional exceptional characteristic of the underground train is that it does not use a single heavy, costly, and technically complicated locomotive, with its unexploited deadweight. In this connection, it should be remembered that a locomotive cannot produce a higher tractive effort than that permitted by the weight on the driving axles and the friction between the wheels and rails. On the other hand, in the case of underground trains, with their multiplicity of driving units, the resulting low axle loading makes it possible to attain higher speeds, in addition to reducing track-maintenance costs. Another important consequence of the design of modern underground trains is that the size of the train can be changed arbitrarily, according to the running frequency, without affecting time-tables, as each coach coupled to the train has its own motors. For the same reason, the train can also be run in either direction without shunting, thus reducing the number of tracks required.

In the case of Sweden, the objection may at this point be raised that the underground railway is built for 600 to 900 V d.c., whereas the Swedish long-distance and suburban railways operate on 15,000 V single-phase a.c., this higher voltage being chosen because of the longer distances involved and the consequent necessity for longer feed sections. With the "Multiplex" train described below, however, a new possibility has been opened up, permitting the use of high-voltage single-phase alternating current and effectively meeting the needs of traffic development for single-phase lines.

The "Multiplex" Train

In the Multiplex train, the single-phase voltage is taken from the overhead line to only one coach in the train, where, by means of an adjustable mains transformer, it is converted to a voltage which is controllable from the driver's cab. This voltage, adjustable between, say, 0 and 4000 V, is distributed over a single-pole feeder, designated the Multiplex feeder, to the coaches in the train, which may, if desired, have motors on all or only some of the axles. Connection of the motors to the Multiplex feeder is effected in each coach over small distribution transformers with fixed outlets and without regulating equipment. The rails form the return circuit for the overhead-line current, as well as for the current in the multiplex feeder. For electric-motor braking, the Multiplex line feeds the field windings of the driving motors, the motor armatures being connected with heating resistances. Each motor drives both axles in a bogie.

In short, then, the Multiplex train incorporates the advantage of the locomotive-drawn train of being able to concentrate the pantograph and ancillary equipment in a single coach but, at the same time, to include the advantage of the underground train of being able to distribute the tractive power evenly over all axles of the train. Thus, as the pantograph coach itself need not be provided with motors for the propulsion of the whole train, it is light and cheap, and may also be exploited for useful purposes, i.e., for luggage, mail, etc. Heavy and increasingly complicated locomotives are thus eliminated, and the weight of the train is evenly distributed over all the axles.

Electric braking (direct-current) in the Multiplex train is effected by connecting the field windings of the motors over small fixed rectifiers to the voltage in the Multiplex feeder, controllable from the cab, while the motor armatures are connected, for instance, to radiators in each coach for heating purposes.

A Multiplex train has been planned for Stockholm's suburban traffic, and will comprise a maximum of fifteen coaches, each equipped with two 200-hp motors, giving a maximum power of 6000 hp. The train, which will be 275 metres in length, will be able to accommodate 1800 passengers and will have a maximum speed of 120 km/hr. The total power of 6000 hp will be sufficient to give the train exceptional starting and braking properties in the inner traffic zones with short distances between the stops, as well as a high maximum speed over longer distances. The axle loading with full load does not exceed 10 tons, and the train permits two-way traffic with the same composition of cars as in the case of the underground railway.

Instead of using thirty 200-hp motors, i.e., one motor for each of the two axles in each bogie, it would, if desired, be quite practicable to plan the train with only one driven bogie per coach with, say, 300-hp motors, giving a total of 4500 hp—a lighter and cheaper alternative. However, in the present instance, despite the (for Swedish conditions) record power of 6000 hp in a complete train (as against 3200 hp in an underground train of eight coaches, and 3600 hp in the most powerful express locomotive in Sweden), the adjustable mains transformer will not be excessively weighty, so that it can still be installed without difficulty in a combined mail and

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luggage van with approximately the same axle loading as in the passenger coaches.

The desirable characteristics of the modern 600–900 V d.c. underground train may thus be transferred to 15,000-V, single-phase a.c. surface trains, with the added advantage of simplified technical arrangements, since the Multiplex train requires only one pantograph and ancillary equipment. An equally large underground train of fifteen coaches would require such equipment on all cars. At the same time, because of the higher voltage of 15,000 V, the overhead-line current to the single coach in the Multiplex train will not be higher than the line current supplied to each of the fifteen coaches in the underground train.

In the Multiplex train, the current to the motors can, if desired, be rectified by means of rectifiers in each coach or a central rectifier in the pantograph coach. Thus, the use of d.c. driving motors is quite feasible. However, in the projected Multiplex train, rectification has in this instance been restricted to braking, as the relatively low magnetization effect on the fields of the motors here permits the use of simple oil-immersed rectifiers. Furthermore, rectification during acceleration has also not been exploited. The reason is partially based on the unfavourable results obtained by rectifying only one phase, as compared with rectifying stations for underground lines, which have 12-anode rectifiers. It is thus not possible to count on a smoothed direct current, as in underground operation; instead, the current is strongly pulsating, with an unfavourable effect on commutation at starting, similar to that obtained with single-phase current. To smooth this strongly pulsating direct current effectively requires costly and bulky resonance circuits.

On the other hand, the Multiplex train permits the possibility of choosing very low motor voltages, as the motors are directly connected with the fixed outlets of the small secondary transformers, without intermediately connected regulating devices.

Experience has also shown that the combination of single-phase motor operation, with a low voltage during acceleration and d.c. operation for braking, affords a very good compromise with reference to the maintenance of the current collectors. It is also inevitable that equipment with rectifiers for acceleration is considerably more complicated and expensive, while, in connection with braking, it is possible to use simple static rectifiers.

Summary of Advantages

The advantages of the Multiplex system can be summarized as follows :—

(1) The Multiplex train permits traffic in both direc-

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GERMANY

The Automatic Recording of Strains Measured with the Maihak Extensometer

By C. Rohrbach. (From *V.D.I. Zeitschrift*, Vol. 98, No. 26, September 11, 1956, pp. 1541–1548, 14 illustrations.)

The growing importance of extensive strain measurements on new structures or experimental designs and the considerable time required for orthodox methods of measurement call for the adoption of automatic procedures, despite the appreciable capital outlay involved. When the Maihak vibrating-wire extensometer is used for measuring semi-static strains, electronic frequency and time counters can be used, and switching arrangements for multi-station tests can easily be incorporated. High frequencies are best measured directly; for low frequencies time can be saved by measuring the duration of one or several periods. Both methods are economical with the Maihak instrument, with which the results can appear printed on a tape in numbers representing the measured strain.

The principle of the Maihak vibrating-wire extensometer is shown in Fig. 1. A frame, with a fixed arm a, is pressed against the surface to be tested c with a force p and carries a solenoid f with leads e. A piano-wire d, passing just below the poles of the solenoid, is stretched between the fixed arm a and the movable support b, the gauge length l_c being approximately 4 in. The initial tension of wire d, which is suitably protected against mechanical damage, can be adjusted. If a direct current is applied to the leads e, the solenoid f exerts a magnetic force on the wire d, deflecting it from its initial position. When the current is switched off, wire d vibrates, with slight damping, at its natural frequency. Thus, a voltage of the same frequency is induced in the solenoid f and can be measured at the ends of the leads e. If a load is applied to the surface to be tested c, the elongation Δl_d of the wire will be slightly less than that of the surface c, so that

$$\Delta l_d = \Delta l_c \frac{A}{A+B} \quad .. \quad .. \quad (1)$$

where $A/(A + B)$ is approximately 0·87.

Now, the well-known equation for the natural frequency n of a vibrating wire of length l_d, stretched by $e_d = \Delta l_d / l_d$ and constructed of a material with a Young's modulus E and density ρ, is

$$n = \frac{1}{2l_d}\sqrt{\frac{Ee_d}{\rho}} \quad .. \quad .. \quad (2)$$

Thus, the test strain e_c can be determined from

$$e_c = \frac{\Delta l_c}{l_c} = \frac{A+B}{A} e_d = \frac{A+B}{A}\left(\frac{2l_d}{\sqrt{E/\rho}}\right)^2 n^2 \quad .. \quad (3)$$

The actual dimensions and material of the instrument lead numerically to

$$e_c = 1{\cdot}75 \times 10^{-9} n^2 \quad .. \quad .. \quad (4)$$

where n is in cps. However, a very thin wire is wound around the piano wire over part of its length, so as to increase the vibrating mass; as a result, the actual relationship, as determined by measurements, has been found to be given very accurately by

$$e_c = 4{\cdot}29 \times 10^{-9} n^2 = Cn^2 \quad .. \quad (5)$$

Thus, e_c remains strictly proportional to n^2.

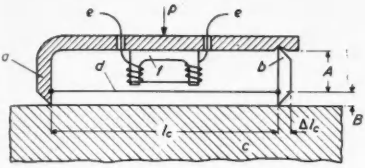

Fig. 1. Schematic representation of the Maihak extensometer.

The usable frequency range is limited to between 250 cps (when the wire is about to contact the pole-pieces of the solenoid) and 1000 cps (corresponding to about 0·4% strain, according to eq. (5), when the danger arises of creep in the wire).

Acoustic Method of Measurement

A testing station (1), selected by a switch *a* (Fig. 2) is connected by a switch *b* to a microphone *h*. The calibrating instrument *d*, with its wire tensioned suitably by a set-screw *e* acting over a toggle *g*, is connected by a switch *c* to a d.c. source *u*. Simultaneous switching of *b* and *c* connects the calibrating wire to the microphone and the test wire to the d.c. source, so that test and calibrating vibrations can be heard alternately. The sounds are equalized by an adjustment of *e* which can be read off on a scale *f*. The difference in the adjustment required before and after strain of the testpiece is a measure of the imposed strain. A similar procedure is used for station (2), etc. Accuracy is greatly increased if, after an initial rough equalization, the frequency of beat between the test and calibrating sounds is made audible by suitable switching of *b* and *c*. A selective amplifier may be incorporated, if the noise level is high.

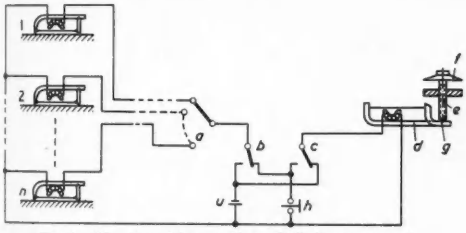

Fig. 2. Circuit used in acoustic method of measurement.

This method is simple and free from disturbances, but is definitely tedious.

Visual Method of Measurement

In this case (Fig. 3), the induced test vibration is amplified at *i* and connected to the Y-plates of a cathode-ray oscilloscope *k*. The calibrating vibration induced in the energizing solenoid *l* and amplified at *m* is led into the feedback solenoid *o*, re-exciting the calibrating wire and eliminating damping. The undamped alternating voltage is connected to the X-plates of *k*. The simultaneous oscillations at the X- and Y-plates create Lissajous figures, equalization producing an ellipse, which shrinks in accordance with the damping of the test wire. Differences of less than 1 cps can be equalized.

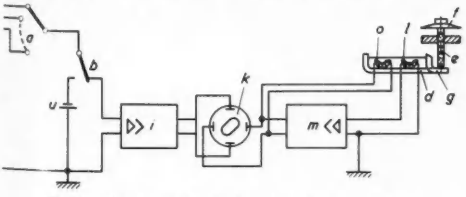

Fig. 3. Circuit used in visual method of measurement.

With this method, measurement is easy, rapid, and accurate, and, although electrical noise may distort the figures, it cannot lead to errors in equalization. Its disadvantages are the expense of the equipment required and the impossibility of automatic testing.

Continuous Recording

For continuous recording (Fig. 4), an electrical standard vibration replaces the mechanical calibrating instrument. The test vibration induced in the solenoid *c* of the extensometer *a* is amplified at *d* and fed back into the solenoid *b*, so as to eliminate damping. An attenuator *e* limits the peak value of the amplified voltage and makes it independent of frequency. The output voltage of the frequency-measuring bridge *f* is proportional to the test frequency. This voltage is amplified again at *g*; it is then rectified at *h*, in such a way that the rectified voltage is proportional to n^2, and hence to e_e in eq. (5), and is finally recorded by *i* as a function of time.

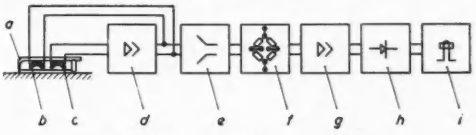

Fig. 4. Block diagram for continuous recording.

The advantage of this method lies in the possibility of providing continuous recording. However, the equipment is expensive, and only moderate accuracy is obtainable. Moreover, an upper limiting frequency of about 300 cps makes it less suitable for measuring dynamic stresses than other methods.

Electronic Counters for Frequency and Duration of Period

Conventional frequency- and time-counting instruments can be used, the frequency or period of the test vibrations being, as before, compared with those of an electrical standard vibration. The technical perfection of these instruments and their speed of operation, which is based on the counting of impulses during a given time, have lead to appreciable advantages and even to new fields of application.

Electronic equipment connected as a frequency counter is illustrated by the block diagram in Fig. 5. The voltage induced by the vibration of the piano wire is passed into a thyratron, which transmits current only during an accurately controlled time interval *t*. The number *m* of voltage peaks or impulses transmitted during this time interval is counted and registered by glow-lamps, moving-coil instruments, counting tubes, or even by printing on paper. The current-transmission and counting process can be repeated after any chosen time interval, the shape of the impulses being immaterial. The time *t* is controlled by a very accurate quartz-stabilized standard high-frequency generator, either directly if one standard period alone permits passage of a sufficient number *m* of test impulses, or indirectly through a decade selector if a multiple of the standard period is required. These multiples are best selected so that $t = 10^x$ sec, where *x* is any integer, because results then appear immediately in cycles per second. If the test frequency is high, a short opening time *t* will keep the number of impulses counted within the storage capacity of the

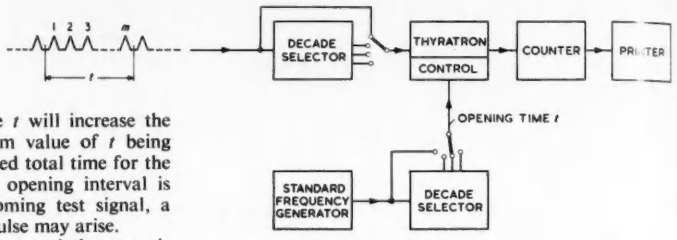

Fig. 5. Block diagram of equipment for measuring frequency.

counter; if it is low, a longer time t will increase the accuracy of counting, the maximum value of t being determined by the available or desired total time for the operation. Since the start of any opening interval is fortuitous with respect to the incoming test signal, a maximum inherent error of one impulse may arise.

Electronic equipment connected as a period counter is shown in the block diagram in Fig. 6. Since the accurate direct measurement of low test frequencies would take an extremely long time (a frequency of 10 cps measured to an error within 0·1% would require 1000 impulses or 100 sec), it is preferable to let one period τ, or any decade $10^x\tau$, of the test vibrations control the opening time $t = 10^x\tau$, and to count, as a measure of τ, the peaks of the standard high-frequency vibrations transmitted during the time t. Here, the possible inherent error is influenced by the fact that delay of the time control cannot be kept rigidly constant. However, this error, which occurs only at the start and the end of each opening interval, is small and becomes even less important as x becomes higher. The standard frequency signals can be grouped and counted in decades, if the storage capacity of the counter is in danger of being exceeded, but such multiplication reduces the accuracy of measurements.

The Practical Measurement of Frequencies

The Maihak extensometer with one solenoid produces damped vibrations which are not very favourable for the measurement of frequency, because small signal amplitudes more easily admit interference by noise or disturbing impulses caused by switching operations, each foreign impulse of this type appearing as a unit error in counting. Damping is already appreciable after 1 sec, a normal counting period. Elimination of damping by means of feedback into a second solenoid would serve to improve matters and would permit an independent choice of the counting period; on the other hand, it would require more expensive instrumentation.

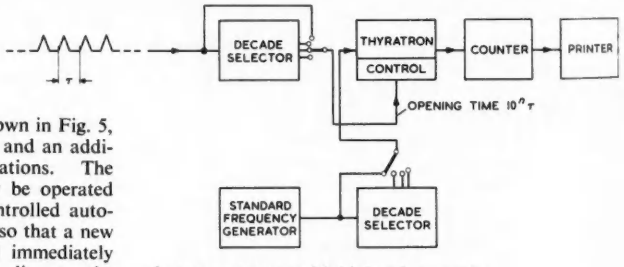

Fig. 6. Block diagram of equipment for measuring period of vibration.

The arrangement is in principle that shown in Fig. 5, with an additional amplifier for the signal and an additional selector switch for the testing stations. The switch, the counter, and the printer may be operated successively by hand, or they may be controlled automatically in sequence by the printer itself, so that a new station is selected during, and measured immediately after, printing the previous result. Depending on the accuracy desired, the time for one measurement may be, say, 1 or 10 sec.

Calibration:—Because, as already mentioned, the frequency range of the Maihak extensometer is limited, the instrument is first set up on the unstressed calibration bar with the wire tensioned to a frequency n_1 corresponding to a fictitious strain e_{c1}. After stressing, the frequency n_2 of the bar will correspond to a strain e_{c2}. The calibration strain $\Delta e_c = e_{c2} - e_{c1}$, measured by other means, then permits determination of the constant C in eq. (5), given that the square law is strictly valid over the entire range, so that

$$C = \Delta e_c/(n_2^2 - n_1^2) \quad .. \quad (6)$$

The calibrating device must be very rigid, as the force exerted by the wire on the measuring points of the instrument is high.

Evaluation:—The strain Δe_c of the testpiece can be determined from two measured frequencies n_1 and n_2 by means of the relation

$$\Delta e_c = C(n_2^2 - n_1^2) = C(n_2 + n_1)(n_2 - n_1) \; .. \quad (7)$$

It is possible to form n^2 electronically, so that the strain can be obtained by simple subtraction. In load-cell or dynamometer applications where the initial frequency n_1 may be fixed and where the sign of the elongation is known, the resulting recorded figure is then immediately proportional to the quantity to be measured. In addition, the frequency of the standard generator may be so adjusted that the printed figure gives directly the quantity required. Such a direct printed record of various quantities measured together will often be worth the additional outlay involved.

Errors:—Stray errors may intrude from the mains frequency and from disturbing impulses, but help may be obtained in eliminating them by means of filters, electrical and magnetic screening, suitable equalizing switching arrangements, and amplification of the test signal. Also, the vibrations of the wire may be picked up by inductive or capacitive proximity meters and superimposed on a carrier frequency in an undisturbed range. The inherent error of one pulse, as already mentioned, becomes greater with higher frequencies.

Differentiation of eq. (5) gives the error in strain due to a measuring error Δn in the frequency as

$$\text{Error} = 2Cn\Delta n \quad .. \quad .. \quad (8)$$

Thus, for example, with a measuring period of 1 sec with $n = 250$ cps and $C = 4{\cdot}29 \times 10^{-9}$, the error in strain is about 2×10^{-6}, and with $n = 1000$ cps it is about 8×10^{-6}. This is usually sufficiently small but, where necessary, any increase in the measuring period will reduce the error correspondingly.

THE PRACTICAL MEASUREMENT OF THE PERIOD OF VIBRATIONS

This method, preferred for low frequencies, also has the advantage of being unaffected by damping, since measurements are taken only over a few vibrations, possibly one period. However, even one single disturbing impulse may falsify results completely.

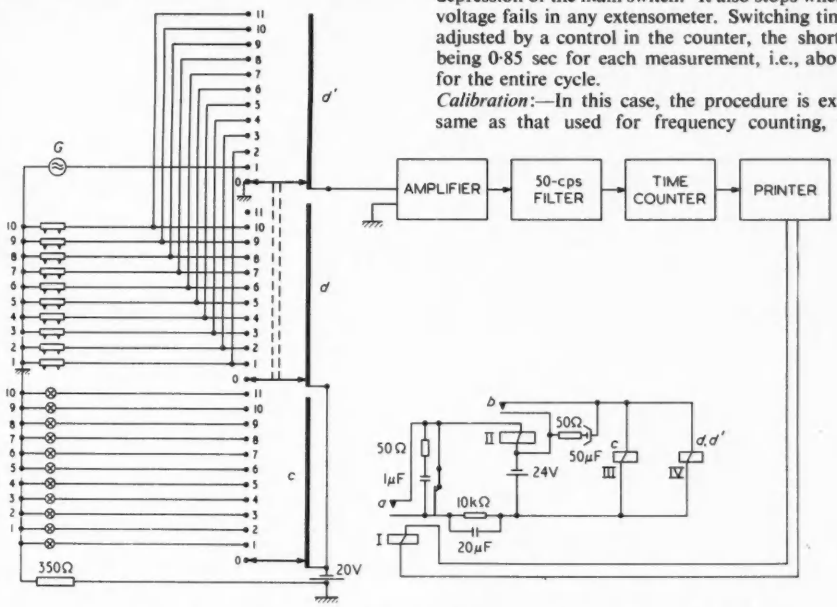

Fig. 7. **Automatic measuring and recording equipment, showing circuit used for measuring period of vibration.**

A suitable automatic measuring and recording arrangement is shown in Fig. 7. Closure of a main switch (the electrical switching impulse is screened by a parallel RC filter) initiates measurement by operating relay II, which closes switch *b* (also with a parallel RC filter); current passes through solenoid III, advancing the decade dial *c* by one step and, through solenoid IV, advancing the interconnected dials *d* and *d'* by one step. The 10-kΩ, 20μF set, in series with relay II, immediately reopens this relay, thus terminating all the disturbing switching operations. Subsequent opening of the switch merely produces a minor current in relay II, and hence no noticeable disturbance. The decades *c*, *d*, and *d'* are now in position (1). The generator *G* is connected to the input side of the amplifier (gain 10,000), and the battery potential of 20V connected to *d* deflects the wire of extensometer (1). The voltage of *G* is increased and fed via a 50-cps filter into a time counter, where its period is measured and is then printed on tape as a reference for the series of measurements to follow. Different series may be marked individually by changing the period of this voltage.

During the interval of mechanical printing, the counter is isolated electrically from all external impulses, so that this is the appropriate moment for the next switching cycle. At the start of printing, the printer energizes relay I, the switch *a* is closed, instead of the now open main switch, and the decade dials are advanced into position (2). The solenoid of extensometer (1) is de-energized, the piano wire vibrates, the induced vibrations being transmitted to the amplifier via *d'*. Extensometer (2) receives the battery voltage via *d* and its wire is deflected. After switching has been completed, the counter is opened, and the period of (1) counted and then printed, this operation being repeated throughout the series. At the end of the series, after transition of the dials from (11) to (0), the whole process is stopped and must be restarted manually by depression of the main switch. It also stops when the test voltage fails in any extensometer. Switching time can be adjusted by a control in the counter, the shortest time being 0·85 sec for each measurement, i.e., about 10 sec for the entire cycle.

Calibration:—In this case, the procedure is exactly the same as that used for frequency counting, the calibration curve having the form $e_e = C/\tau^2$, and C being determined from calibration measurements from

$$C = \frac{\Delta e_e}{\tau_2^2 - \tau_1^2} \quad .. \quad .. \quad (9)$$

The usual value of C is once again $4{\cdot}29 \times 10^{-9}$, where τ is in seconds. In accordance with the frequency limits (250 to 1000 cps), the duration of one period is limited to between 4 and 1 millisec.

Evaluation:—The same relations apply in this case as for frequency measurements, but the necessity for calculating the reciprocal of τ^2 gives rise to some added complications. Electronic evaluation is again possible.

Errors:—Electrical disturbances are virtually excluded with this arrangement. Inherent errors comprise the finite delay of the time control and the possible variation by one impulse of the impulses counted by the standard generator.

Differentiation of $e_e = C/\tau^2$ shows that the error in strain due to a measured error $\Delta\tau$ in the duration τ of one period is

$$\text{Error} = 2C\,(\Delta\tau/\tau^3) \quad .. \quad .. \quad (10)$$

Thus, if 10 vibrations are measured out and the frequency of the standard generator is 1 Mcs, the error in $\Delta\tau$ due to miscounting of one impulse is 10^{-7} sec. The error in strain is then approximately 10^{-8} with $\tau = 1/250$ sec, or about 10^{-6} with $\tau = 1/1000$ sec. These results are accurate enough, and in practice the total error is in fact of the same order of magnitude.

Schlieren Investigations into Air-Flow Conditions in Modern Air-Blast Circuit-Breakers

By W. PUCHER. (From *ASEA Journal*, Vol. 29, No. 9, 1956, pp. 107–112, 12 illustrations.)

As indicated in the article on "The Testing of High-Voltage Circuit-Breakers" in our issue of November 1956, schlieren methods are of value in investigating air-flow conditions in air-blast circuit-breakers. In the following article it is shown how schlieren investigations help to measure changes in the density of the flowing air and to render flow lines visible, so as to provide direct information on the suitable design of air-flow channels and contacts.

THE demands made on the breaking capacity at rated voltage of modern high-voltage circuit-breakers are increasing, and considerable breaking capacity at breaking voltages far in excess of the rated voltage is also required. Very high voltages occur in the circuit-breaker, for example, when breaking a line under no-load or during phase opposition. In the case of air-blast circuit-breakers, this means that the air blast must be able to extinguish rapidly the arc of the short-circuit current, and that the dielectric strength between the open contacts must be adequately high, if breaking is also to be carried out at extreme voltage stresses.

These two extreme cases impose on the circuit-breaker different demands, which very often conflict with each other; in other words, a measure which improves the breaking capacity at normal service voltage can reduce it at a higher voltage and *vice versa*. Thus, for example, a greater contact distance gives higher dielectric strength, but, at the same time, a greater length of arc and consequently an increase in arc energy. Furthermore, in circuit-breakers with axial blast, the arc is drawn out into a region with a lower speed of air flow. As a result, it may be difficult for the circuit-breaker to interrupt the current. The design of the contact constitutes another example. At a given contact distance the more homogeneous is the electrical field between the contacts, i.e., the greater the radius of the contact surface, the greater is the dielectric strength obtained. However, blunt contacts usually have a deleterious effect on air flow and consequently on breaking capacity.

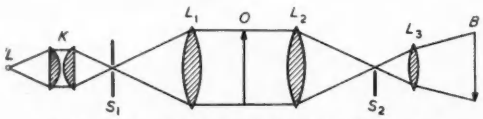

Fig. 1. **Diagrammatic representation of a schlieren system.**

It follows from the above that the final design of the contacts and the choice of a certain contact distance is always the result of a compromise between the demands of these two extreme cases. It is therefore essential to utilize all the energy in the compressed air and to use it as effectively as possible. To determine the best contact shapes and types of air-flow channel solely by means of breaking tests in the short-circuit laboratory is an expensive and lengthy procedure, and does not significantly increase knowledge of those air-flow factors which are of vital importance for breaking. Consequently, it is important to obtain further information on the flow of the compressed air by means of other investigations, in order to utilize better the extinguishing capacity of the compressed air on the arcs. A particularly suitable aid in air-flow investigations is the schlieren method.

If, in a transparent, homogeneous medium, there are small areas, the index of refraction of which differs somewhat from the normal value, light entering these areas is refracted. The amount of deviation depends on the change in the index of refraction and on the shape of the area, which is called a striation field, or "schlieren". In connection with schlieren measurements, the term "schlieren" is extended somewhat and is used to describe each irregular refraction of light occurring in a relatively small area. The schlieren method makes it possible to register and measure small light refractions. The method used in the present investigation is due to Toepler and is shown diagrammatically in Fig. 1.

Light from the light source L is arranged to converge on the pin-hole aperture S_1 with the aid of a condenser lens K. The pin-hole aperture sharply limits the rays of light and is situated at the focal point of lens L_1, thus transmitting parallel rays of light to lens L_2, which concentrates the rays again at its focal point, where a knife-edge S_2, is located. The knife-edge can be moved in its plane, i.e., at right-angles to the plane of the figure, and set so that approximately half the rays of light pass over the edge, while the rest of the light is stopped. If all the light is passing through a homogeneous medium, the field B will be evenly illuminated. If an object O, e.g., a current of air, is now introduced into the parallel rays of light between lenses L_1 and L_2, this will cause slight refraction of the passing rays, whereupon more of the light going through such places in the object which cause an upward deviation passes over the top of the knife-edge than would be the case without deviation. If the light rays are refracted downwards, less light, or no light at all, will pass through. If the lens L_3 depicts the object O sharply on a viewing screen or a photographic film, a picture B of the object O is obtained, on which the points which cause an upward deflection of the light appear light, and those which cause a downward deflection dark. Thus, the schlieren method makes the light deflections visible through changes in the brightness of the image B. The intensity of the light on the screen is a function of the component of light refraction at right-angles to the knife-edge. The light refraction can be determined by photometry of the image. Furthermore, light refraction is proportional to the component of the index of refraction gradient at right-angles to the knife-edge. When measuring with the knife-edge turning about the optical axis in two positions at right-angles to one other, the total gradient can be determined if the object is two-dimensional, or if there is symmetry. However, when investigating air flow, it is mainly the thermodynamic, and not the optical, condition which is of interest.

If each individual schlieren image is to be interpreted correctly, the position of the knife-edge must be known. The position of the knife-edge is normally given on the images by means of a diagrammatic schlieren image of the positive lens, which, with reference to light refraction, is analogous with a non-homogeneous medium.

MEASURING EQUIPMENT

The complete measuring equipment for air-flow investigations of air-blast circuit-breakers is so arranged that the source of light used can be either an electric spark

Fig. 2. Air flow around a conical plug contact (top angle =120 deg.) at the initial stage of a discharge.

Fig. 3. Air flow around a conical plug contact (top angle = 120 deg.) during the intermediate stage of a discharge.

or a high-pressure mercury lamp. The spark can be set off, either by means of a drum controller, which also controls the release of air flow through the circuit-breaker under test, or directly by a contact which closes as soon as air begins to flow. In addition, by means of a suitable device, ignition of the spark can be delayed, within certain limits, in relation to the beginning of air flow. The illumination time of the spark is 2 microsec, which guarantees sharp pictures, even in the case of rapidly changing air flow. The high-pressure mercury lamp, which burns continuously, is used for motion pictures. However, if the same quality of picture is required, the speed of the camera must be very high.

The circuit-breaker element, or a model thereof, is located between the lens systems and is fitted with special windows, so as to permit light to pass through that part of the air flow to be investigated. Thus, measurement can be carried out without taking any steps which would interfere with the flow. Neither is measurement limited to a single point, but covers a major area which is limited only by the size of the lenses in the optical system. The circuit-breaker element is connected via a valve to a tank which is supplied with compressed air from a compressor. The air pressure in the tank can be varied, and the stream of air through the circuit-breaker element is released by means of the valve. When carrying out investigations on a scale model, care must be taken to ensure that the air flow is changed in accordance with the same scale, i.e., certain relations between geometric, aerodynamic, and thermodynamic quantities must be maintained. Naturally, this also applies to the air-flow channels and valves. It is often advantageous to design a model so that the air flow is essentially in one plane.

Fig. 4. Air flow around a conical plug contact (top angle = 120 deg.) at maximum speed.

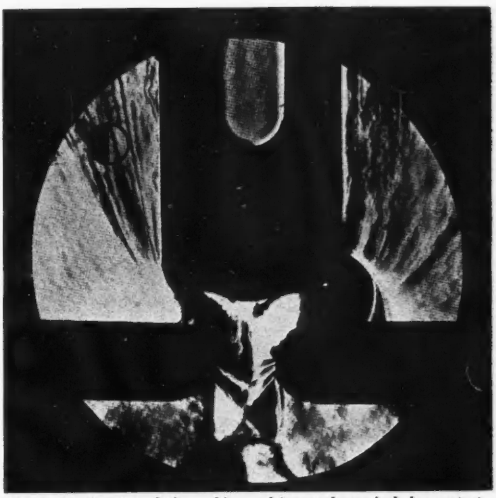

Fig. 5. Air flow (speed of sound in nozzle) around a conical plug contact (top angle = 150 deg.), showing a disturbance wave between contacts.

The schlieren method integrates all light refraction along the path of the light. Schlieren images of two-dimensional air flow are therefore considerably easier to interpret than pictures of three-dimensional flow. However, from schlieren images of rotationally symmetrical flow, which, in practice, is always found, it is possible, just as exactly, even though perhaps not quite as easily as is the case with two-dimensional flow, to arrive at the field of density.

Schlieren Photographs

The photographs taken in this investigation were made during no-load operation of the circuit-breakers, i.e., with no arc between the contacts. The reason for this was that the radiation from the arc would have completely dominated the light source of the schlieren system. Naturally, the question then arises whether such pictures can give any information as to the extinguishing capacity of the air flow on the arc. Experience, however, shows that this is the case, the explanation probably being as follows :—The inflow of cold air to the nozzle is insignificant as long as the arc is burning, i.e., as long as it heats the air. It is not until the short-circuit current approaches zero and the supply of heat ceases that an effective air flow comes into being and then accomplishes the extinguishing operation. Thus, during the extinguishing sequence, the conditions are approximately the same as in the case of an air flow without an arc, with the difference that the temperature is higher. In these experiments, the circuit-breaker model was directly connected to the compressed-air tank and from the beginning was filled with compressed air, whereupon air flow was released. When discharging in this way, the air-flow speed at the nozzle contact rises from zero to the speed of sound. To begin with, the flow is laminar, as shown in Fig. 2, in which the direction of flow is indicated by the arrows. Below the nozzle contact (on the outflow side) two eddies arise. The flow lines are clearly visible. During a later phase, with increased speed the air current forms a jet from the nozzle downwards and no longer follows the walls of the channel. However, between the contacts it is still laminar (Fig. 3), the flow lines mapping out the direction of flow in the whole area. In Fig. 4, the flow has finally reached its maximum, with the speed of sound

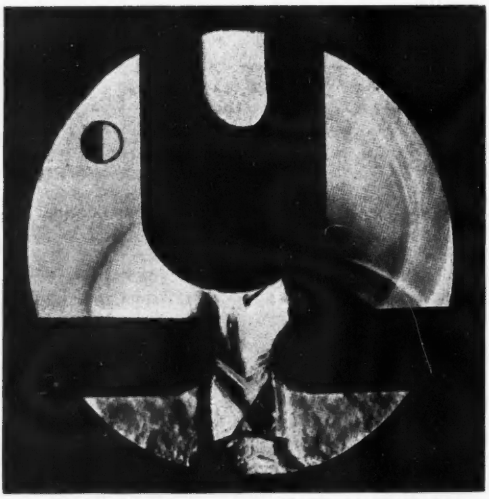

Fig. 6. **Air flow (speed of sound in nozzle) around a spherical plug contact, showing disturbance waves arising against the flow.**

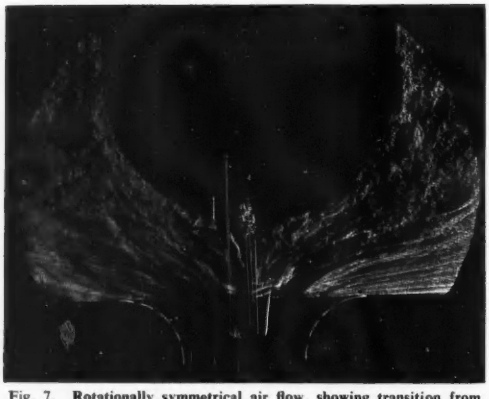

Fig. 7. **Rotationally symmetrical air flow, showing transition from laminar to turbulent flow during discharge.**

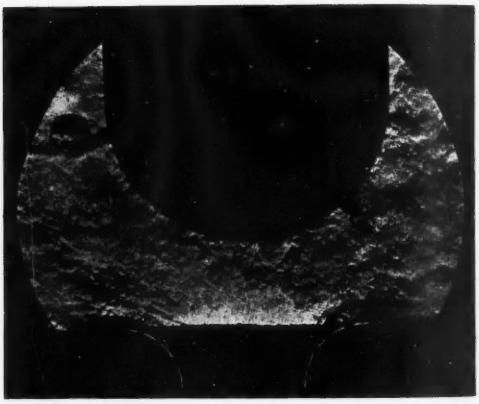

Fig. 8. **Rotationally symmetrical air flow (speed of sound in nozzle), showing turbulence.**

in the nozzle and expansion to supersonic speed beyond the nozzle, where compression and expansion fronts occur. Between the plug and nozzle contacts, density is at a maximum along the axis of symmetry of the picture and two minima along both sides, approximately at the shortest distance between the contacts.

The magnitude of the influence of the contact shape on the air flow can be seen from Figs. 5 and 6, in comparison with Fig. 4. The only difference in the experimental conditions was the shape of the plug contact : otherwise, these photographs were taken under exactly the same conditions. The air flow here leaves the surface of the plug contact at a much earlier stage, and in front of the point a " dead-water " area is formed. Furthermore, the position of the flow between the contacts is not stable laterally. Disturbance waves arise and develop against the air current.

Examples of schlieren photographs of a rotationally symmetrical air flow are given in Figs. 7 and 8. The nozzle is not visible and its contours have been inserted by means of dotted lines. Fig. 7 shows the stage in a discharging operation when the air flow leaves a laminar phase and enters a turbulent phase, while in Fig. 8 the air flow has already become quite turbulent, i.e., local

changes in density are distributed at random over the entire air flow and can only be related statistically to temperature and pressure. In the white area in front of the nozzle (Fig. 8), density falls and flow speed increases —completely in accordance with the laws governing adiabatic changes.

However, it is not only a question of discharging an air-blast circuit-breaker. Depending on the mode of operation, the charging of the breaker, as well as the releasing and stopping of the air stream, also has great significance. If, for example, a blast-valve on the outflow side closes and causes the flow to cease, this brings about reactions on the air flow around the contacts in the form of major changes in density. The changes have a turbulent character and spread like a reflection wave against the air flow.

U. S. A.

Performance Tests on Ceramic and Carbide Tools

By A. O. Schmidt, I. Ham, W. I. Phillips, and C. F. Wilson. (From a paper presented at the *ASME Annual Meeting, New York*, November 25–30, 1956, 44 pages, 24 illustrations.)

This report summarizes the findings of a series of comparative laboratory and shop tests with ceramic and carbide tools. Increased rigidity, adequate speed and feed ranges, and sufficient power must be provided in machine tools to utilize the full potential of ceramics. The inevitable improvement in machine conditions fostered by these materials will also help to improve the performance of carbide and high-speed steel tools. These ceramic materials will thus at the same time be an aid and a challenge; for example, recently developed carbides and cermets compete with ceramics at speeds and feeds recommended for ceramics.

Either at present or in the near future many metal-working shops must consider production applications of ceramic cutting-tool materials. For a long time, ceramics for this purpose have been tested in the laboratory and some have already found successful application in production set-ups.[1] These materials have seen great improvements within the past year, but, as with every new development, at the start a number of obstacles must be overcome, and various considerations should be kept in mind when contemplating the use of ceramics.

Ceramics are not a cure-all. Excessive vibration in a machine tool, looseness in the slides, and deflection in the workpiece and tool are likely to cause immediate failure in ceramic tool tips, whereas, under the same conditions, a strong grade of carbide can perform quite satisfactorily.

With an increase in cutting speed there is an increase in volume of metal removed per unit time and a corresponding increase in power required. Since ceramics usually cut between two and three times as fast as carbides, the power required will be higher in the same proportion. However, a machine designed and powered for use with carbide tools, and in good working condition, will usually do a creditable job with ceramic tools.

Operators and foremen in the shop must be briefed thoroughly about the possibilities and limitations of ceramics, as well as the requirements of chip guards. Initially, it is advisable to confine tests to a single machine tool and to try to machine those aluminium, plastic, cast iron and steel workpieces which, because of abrasiveness, entail excessive wear on carbide tools. A job which is tooled up completely with carbide tools and gives optimum results will usually not be improved simply by converting to ceramic tools. On such jobs, carbide tools may even prove to be superior to ceramics.

Difficult, interrupted cuts with attendant mechanical shocks which certain carbide tools can withstand may cause the more brittle ceramic tools to fail. However, even rough forgings and castings have been successfully turned with ceramic tooling after a certain amount of experience has been acquired. The ceramic tools used in these tests were of an aluminium oxide type, having high resistance to mechanical impact and thermal shock, together with high hardness and inertness to chemical attack at the temperatures encountered in metal cutting. Ability to withstand very abrasive conditions will be one of the major assets in the application of ceramics as tools.

The alumina ceramics on the market to-day usually contain between 80 and 95% aluminium oxide,[2] most of the alumina being combined in crystal form. Some of it becomes part of the glass film required for good intercrystalline growth and vitrification. Ceramics are appreciably harder than carbides at higher temperatures.[3]

Test Procedure and Results

Preliminary tests on tool life and wear were made with workpiece materials of AISI 1045 steel, AISI 4150 steel, and high-strength cast iron, with respective Brinell hardnesses of 200, 190, and 190–210, the corresponding testbar dimensions being 5·25 in. diameter × 31 in.; 5·82 in. diameter × 12·9 in.; and 6·50 in. diameter × 30 in. × 3·0 in. i.d. The nominal percentage composition of AISI 1045 steel is 0·43–0·50 C, 0·60–0·90 Mn, and up to 0·04 P and 0·05 S. AISI 4150 steel contains 0·48–0·53 C, 0·75–1·00 Mn, 0·20–0·35 Si, 0·80–1·10 Cr, 0·15–0·25 Mo, and up to 0·04 P and 0·04 S.

Of the several types of workpieces tested, two examples are an elevating-screw drive sleeve of AISI 4150 and a driver pulley of high-strength cast iron, the drive sleeve being made of hot-rolled round bar stock requiring heavy roughing cuts, and the driver pulley being a casting with irregular surfaces necessitating interrupted cuts on both sides.

Although several of the various makes and grades of ceramic tool tip materials available were tested, this report is concerned primarily with one type of $\frac{3}{16}$ in. thickness in two forms, i.e., (1) hexagonal tips, $\frac{1}{2}$ in. across flats, and (2) $\frac{3}{4}$ in. square tips. The hexagonal inserts were used for turning, and the square bits for facing and rough turning. Both tips required special tool holders.

Sintered carbide tools—as recommended and used for machining steel and cast iron in the shops of the Kearney & Trecker Corporation, Milwaukee, where all the tool-life and calorimetric tests described in this report were carried out—were tested concurrently with the ceramic tools for purposes of comparison.

Frequent observations and measurements of the wear land during cutting operations were made with a Brinell microscope. Terminal-wear measurements were taken with a toolmaker's microscope (× 50). Photomicrographs of wear failure and breakage of tool tips were taken with special microscopes and attachments. As the cutting speed was increased, control of fast-moving chips ejected during the cutting operation became more difficult. Carbide chip-breakers, as furnished with the tools, were used in turning steel. In cast-iron machining operations, a shield above the tool tip was provided to protect the operator from the spray of flying chips.

Since the primary object of these tests was to determine optimum cutting conditions for ceramic tool applications in a production shop, it was necessary to select some reasonable ranges of speeds both applicable to and available in present-day machine tools. Tool-life tests without a cutting fluid under the conditions listed below were carried out to a terminal flank wear of 0·008 or 0·010 in. in most instances. Several tests were continued to the point of destructive failure or breakage, in an effort to determine the cause and nature of ceramic tool failure.

Speed range [fpm]		Feed [in./rev.]	Depth of cut [in.]
Ceramic	Carbide		
1000–400	400–200	0·016	0·160
1000–400	400–200	0·010	0·100
800–400	300–150	0·010	0·280

The results of the tests showed that the improvement in performance of ceramic tools in comparison with carbide tools is more pronounced at higher than at lower cutting speeds. In fact, at lower speeds some grades of carbide can perform equally as well as, or better than, ceramic materials. At higher cutting speeds, under proper conditions, ceramic tools may remove from two to four times more volume of metal than carbides in the same length of time with equal tool life in terms of cutting time. With ceramic tools, AISI 4150 steel showed better machinability than AISI 1045. In this connection, microscopic examination of AISI 1045 showed definite banding of ferrite and large pearlitic grain size, while AISI 4150 had a uniform distribution of finer pearlitic grain size. With carbide tools this situation was reversed. At about 320 fpm cutting speed, tool life was the same for ceramics and carbides when machining AISI 1045. At lower speeds the carbides were superior, and at higher speeds the ceramics gave better performance.

Special alloy cast irons used for machine-tool parts have frequently been more difficult to machine with carbides than have steels. With ceramic tools these same cast irons are more easily machined than steels, apparently because of the favourable abrasion-resistance characteristics of ceramics.

Because of the large quantities of workpiece material that can be consumed and the time and expense involved in extensive tool-life tests, data points, one each at a low, medium, and high speed, are considered sufficient to provide a reasonably accurate tool-life curve. It has been the practice of the Kearney & Trecker Corporation to try ceramics on production jobs in which extremely rapid or excessive tool wear is encountered with carbides. Cutting conditions for ceramics on these jobs, as established with the aid of tool-life curves, have worked out very well and indicate that these curves can be used for practical purposes. Typical comparative tool-life curves for ceramic and carbide tools are shown in Fig. 1.

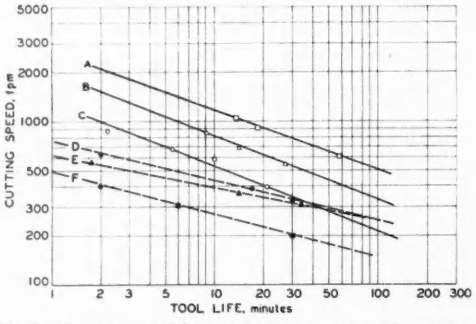

Fig. 1. **Comparative tool-life tests for ceramics and carbides, with a feed of 0·016 in./rev. and a depth of cut of 0·160 in.**
(A) Hexagonal ceramic tip ; high-strength cast iron ; terminal flank wear 0·010 in.
(B) Hexagonal ceramic tip ; AISI 4150 ; terminal flank wear 0·008 in.
(C) Hexagonal ceramic tip ; AISI 1045 ; terminal flank wear 0·010 in.
(D) Brazed carbide tool ; AISI 1045 ; terminal flank wear 0·010 in.
(E) Brazed carbide tool ; AISI 4150 ; terminal flank wear 0·010 in.
(F) Brazed carbide tool ; high-strength cast iron ; terminal flank wear 0·010 in.

Wear Process and Tool Failure

The nature of the wear process and failure in individual ceramic tool tips was observed carefully with the aid of a microscope and recorded. Several photographs of typical ceramic tool wear and breakdown were taken. Top wear and flank wear are illustrated in Figs. 2 and 3. The darkened areas in Fig. 2 on the top or rake surface of the tip are not crater wear but are trace marks of chip flow and bearing marks left by carbide-faced chip-breakers. In a cursory examination the appearance of flank wear on ceramic tools is similar to that on carbide

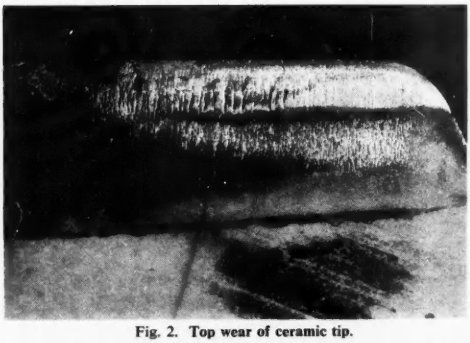

Fig. 2. **Top wear of ceramic tip.**

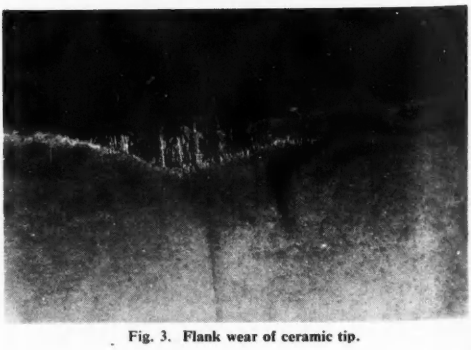

Fig. 3. **Flank wear of ceramic tip.**

tools. On closer inspection, however, a difference in the appearance and nature of the wear process can be detected.

During the first few seconds or minutes of cutting, depending on the cut, only minor chipping (approximately 0·001 to 0·005 in. along the line of the cutting edge) can be observed. This chipping of the sharp edge occurs quickly and then progresses more slowly. Unless careful observations are made, it is easy to misinterpret this initial stage of wear as flank wear similar to that occurring in carbides. It has been found that honing of the sharp edge delays the initial chipping process, or extends the time over which it takes place. Honing a flat, approximately 0·003 in. wide, on the cutting edge is to be recommended as a means of increasing ceramic tool life.

As cutting proceeds, minor chipping begins and progresses on the flank of the tip, until the total width of wear land measures approximately 0·005 to 0·010 in. After this amount of wear has developed, the flank wear on a ceramic tip, at first sight, may appear the same as on a carbide tip. Careful observation reveals minor chipping along the cutting edge and succeeding flank wear, as shown in Fig. 4, which indicates several possible stages in the progression of wear.

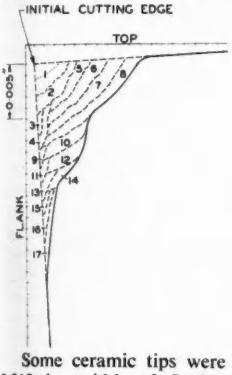

Fig. 4. Cross-section of typical ceramic tip wear.

Some ceramic tips were operated beyond 0·008 to 0·010 in. width of flank wear, and continued wear appears to take place in a fashion similar to that illustrated in Fig. 4, with the flank wear having the appearance shown in Fig. 5. Under certain conditions (such as poor seating of the tip or heavy, interrupted cuts) major chipping on the top or rake surface, and fracture in the middle of the tip or complete breakdown of the nose, may occur. By the time that 0·010 to 0·030 in. of flank wear has been attained, it is very likely that other types of failure will have occurred, such as major chipping on the cutting-edge shoulder or nose or gross cracking or fracture (Fig. 6). For this reason it may not be good practice to cut with ceramic tools to a flank wear of 0·030 in., as is quite common with carbides. It is better practice to index or regrind the tips when they have been worn on the flank to a width of about 0·010 to 0·015 in.

Among the causes of failures and breakdowns are improper cutting conditions, tool material, tool holder (especially carbide seat or pad), chip-breaker, and tool angles. Fracture of the tool tip, as shown in Fig. 7, occurred at the beginning of cutting because of improper carbide seats or pads. These seats must be uniformly flat and rigid to support the ceramic tip without setting up stress concentrations in the tip. Tool life was affected by tool material and structure, but not by the tip sizes used

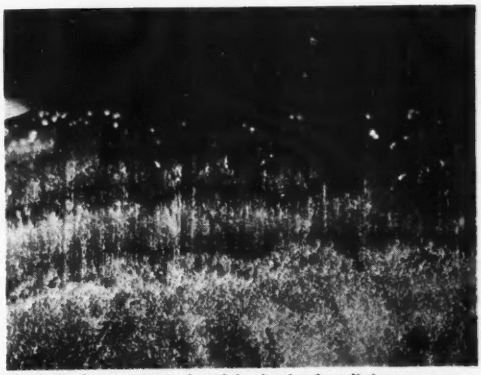

Fig. 5. Flank wear on ceramic tool tip, showing three distinct wear areas.

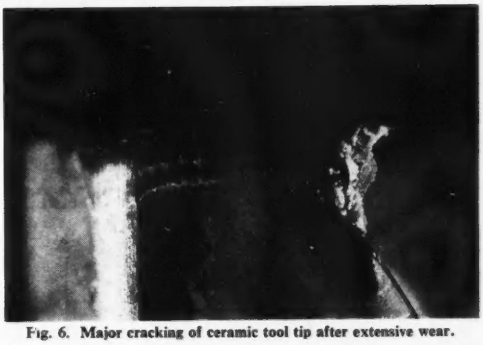

Fig. 6. Major cracking of ceramic tool tip after extensive wear.

in these tests. A fine crystalline structure, permitting only minor chipping, seems to be best from the standpoint of tool life.

No crater wear (as observed in carbides and high-speed steel tools) could be detected on the ceramic tips tested. What may often appear to be cratering actually is an accumulation of metal particles lightly adhering to (but not welded to) the tool tip under the high temperatures usually associated with high cutting speeds. Wear by welding of particles of the tool material to the moving chip (of a degree experienced in crater wear of carbides) does not seem to apply as an explanation of the wear process involved in machining metals with ceramics.

Since crater wear did not occur, flank wear was selected as the measure of tool life. A number of patterns

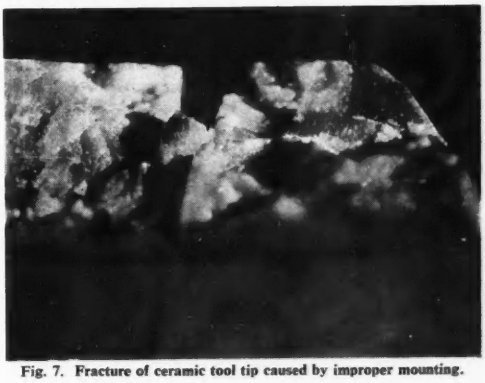

Fig. 7. Fracture of ceramic tool tip caused by improper mounting.

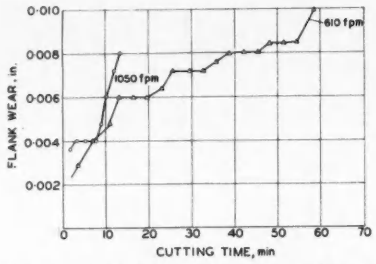

Fig. 8. Flank wear of ceramic tools related to the time for cutting high-strength cast iron at various cutting speeds, with a feed of 0·016 in./rev. and a depth of cut of 0·160 in.

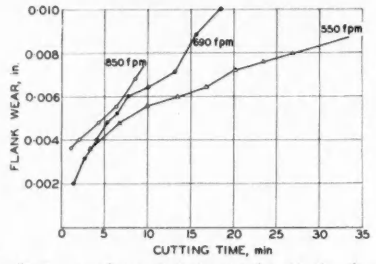

Fig. 9. Flank wear of ceramic tools related to the time for cutting AISI 4150 steel at various cutting speeds, with a feed of 0·016 in./rev. and a depth of cut of 0·160 in.

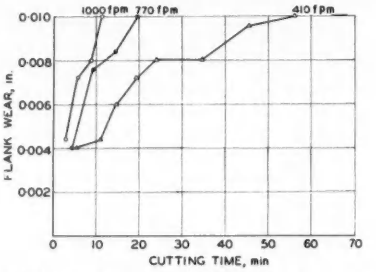

Fig. 10. Flank wear of ceramic tools related to the time for cutting AISI 1045 steel at various cutting speeds, with a feed of 0·010 in./rev. and a depth of cut of 0·100 in.

in the relation between flank wear and cutting time under various conditions can be seen in Figs. 8, 9, and 10. A nearly linear relation above an initial flank wear of about 0·004 in. can be seen at 1050 fpm in Fig. 8 and in all the curves in Fig. 9. Progress of flank wear in a stepwise fashion can be seen at 610 fpm in Fig. 8 and 410 fpm in Fig. 10.

With carbide tools a linear wear-time relation between approximately 0·002 to 0·015 in. width of flank wear, with much more rapid wear below and above these limits, is not uncommon,[4] and is substantially similar to the linear relation reported here for ceramics after a rapid initial wear of about 0·004 in. has taken place.

The process involved in rapid initial tool wear merits further investigation, as does the stepwise progress of flank wear noted in some of these tests. This phenomenon, in which the width of wear land on a ceramic tool tip may not change measurably at all during an increment of several minutes of cutting time, has never, to the authors' knowledge, been encountered with carbide tools and was perplexing when first observed. When the flank wear does not increase during several minutes of cutting, wear occurs in another direction, in a fashion such as indicated by areas 5, 6, 7, and 8 in Fig. . The appearance under the microscope of this type of wear on ceramic tools differs from that on carbide tools.

An important problem in application of ceramic tools is adequate protection of the cutting edge against work-hardened chips which strike the cutting edge outside the region of cutting, causing major chipping and subsequent breakage. This situation can be materially improved by using a proper side-cutting-edge angle and chip-breaker especially shaped so as not to permit the chip to impinge on a part of the cutting edge which is not actually cutting. If the tip is sufficiently well protected against major chipping and breakage, ceramic tools frequently wear uniformly. Under these conditions, ceramics cut as well as any other material and often have better tool life.

When a carbide used on a job is wearing too rapidly on the flank or by cratering, substitution of a harder grade of carbide may be the best solution. If this harder carbide still wears away at a high rate, then ceramics should be tried if set-up conditions are rigid and the power capacity of the machine is sufficient. Because of their higher hardness at elevated temperatures ceramics may be the better tools.[5]

Application of Test Data

Tool life in terms of the volume of metal removed at various cutting speeds is shown in Fig. 11, and at various production or metal-removal rates in Fig. 12. Fig. 11 shows how the volume of metal removed changes in relation to the feed and depth of cut for the same ceramic tool wear (0·008 in. flank wear). For example, at 600 fpm (A) produces a greater volume of chips than (B), but at 340 fpm there is no difference. Under comparative cutting conditions, Fig. 11 also shows that a great increase in volume of metal removed can be obtained by using a ceramic instead of a carbide tool for machining a high-strength cast iron. For example, at 0·010 in. flank wear, a carbide tool removed a total of 25 cu in. of metal at 400 fpm, while a ceramic tool cut a total of 1090 cu in. at 600 fpm.

When cutting speed was increased, the rate of metal removal was increased, but at the expense of a decrease in tool life in terms of metal volume removed. The rate of metal removal is also increased as feed and depth of cut are increased, but with accompanying changes in tool life. Therefore, it is possible to select an optimum cutting speed, feed, and depth of cut for a desired shop application, rate of metal removal, or tool life by studying these relationships and curves.

The cast-iron pulley, which was to be rough-turned, required a comparatively slow cutting speed with carbide tools because of excessive abrasive tool wear. An analysis was made of the production cost for this workpiece with carbide tools and with ceramic tools. The load-and-idle cost, which includes such items as loading and unloading the piece, crane time, and tool approach, was identical for both ceramic and carbide tools. This item falls under the category of the most expensive production cost, i.e., materials handling. The cutting cost is the actual cost of removing metal and, as the metal removal rate is increased, this cost is decreased, owing to the shorter duration of cutting time. Because of rapid increases in the wear rate of the tool with increased speeds, the tool cost increases very rapidly as the speed is raised. A rapid wear rate necessitates more frequent tool changes and an increase in tool-changing cost. The sum of these costs is equal to the total cost of production.

The total cost curve for ceramic tools was found to be much flatter and lower than for carbide tools, the optimum cutting speed for this cast iron with a ceramic tool being 500 fpm and 100 fpm for a carbide tool. It should be noted that the cutting, tool, and tool-change costs for the ceramic tool are considerably below the load-and-idle cost, whereas these costs constitute a larger share of the costs when using a carbide tool material. The rate of increase for tool cost is greater for carbides than for ceramics within the practical operating ranges. Owing to the poor machinability of the cast iron, a feed of 0·010 in./rev. was expedient for the carbide tool, while a feed of 0·016 in./rev. could be used with the ceramic tool. This difference in feed was an advantage for the ceramic tool, since the cutting-cost factor is inversely proportional to feed. An analysis of this type not only evaluates the optimum savings in tool costs, but also indicates at which point or speed this can be achieved.

Cutting Forces and Power Requirements

Tool-force measurements were made with a three-component, strain-gauge lathe dynamometer, using new, sharp tool tips of both ceramic and carbide with the same

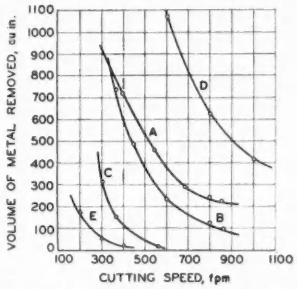

Fig. 11. **Life of ceramic and carbide tools, expressed as volume of metal removed, related to cutting speed, when cutting AISI 4150 steel (curves (A), (B), and (C)), and high-strength cast iron (curves (D) and (E)).**
(A) Ceramic tool ; terminal flank wear 0·008 in. ; feed 0·016 in./rev. ; depth of cut 0·160 in.
(B) Ceramic tool ; terminal flank wear 0·008 in. ; feed 0·010 in./rev. ; depth of cut 0·280 in.
(C) Carbide tool ; terminal flank wear 0·008 in. ; feed 0·016 in./rev. ; depth of cut 0·160 in.
(D) Ceramic tool ; terminal flank wear 0·010 in. ; feed 0·016 in./rev. ; depth of cut 0·160 in.
(E) Carbide tool ; terminal flank wear 0·010 in. ; feed 0·016 in./rev. ; depth of cut 0·160 in.

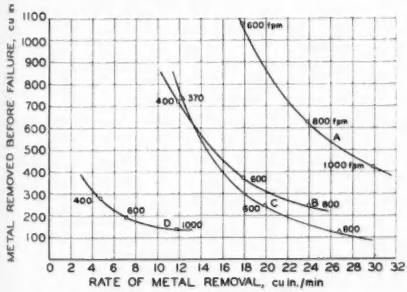

Fig. 12. **Life of ceramic and carbide tools, expressed as volume of metal removed, related to rate of metal removal.**
(A) Ceramic tool ; terminal flank wear 0·010 in. ; feed 0·010 in./rev. ; depth of cut 0·160 in. ; material cut, high-strength cast iron.
(B) Ceramic tool ; terminal flank wear 0·008 in. ; feed 0·016 in./rev. ; depth of cut 0·160 in. ; material cut, AISI 4150 steel.
(C) Ceramic tool ; terminal flank wear 0·008 in. ; feed 0·010 in./rev. ; depth of cut 0·280 in. ; material cut, AISI 4150 steel.
(D) Carbide tool ; terminal flank wear 0·010 in. ; feed 0·010 in./rev. ; depth of cut 0·100 in. ; material cut, AISI 1045 steel.

geometry and operating under otherwise identical conditions. Readings were taken at the beginning of the cuts to eliminate any significant change in tool geometry due to wear. Sharp ceramic tools consistently operated with approximately 5% lower cutting force than the carbide tools. At the same cutting speed and metal-removal rate, therefore, sharp ceramic tools require only approximately 95% of the power required by carbides. This figure is higher than the 80% value reported by other investigators.[6] However, this slight power advantage of ceramics is practically lost as tool wear progresses. Moreover, since ceramics operate effectively at higher cutting speeds and rates of metal removal than carbides, machine tools must have greater power available for machining the same workpiece with ceramics than with carbides, in order to utilize the full potential of ceramics. One of the prerequisites for successful machining with ceramics is the selection of a machine tool which has performed satisfactorily with carbide tools and has a reserve power capacity adequate to cut at the increased rates of metal removal associated with ceramics. Overloading a machine can result in detrimental oscillations in cutting velocity and excessive deflections in the cutting-tool assembly, workpiece and holding fixture, and machine components, all of which may, and often do, cause ceramic tool failure by gross chipping or fracture.

Calorimetric measurements of heat in the tool tip indicate that under identical conditions a far greater amount of heat accumulates in a carbide tool than in a ceramic tool tip. The tool holder also experiences a greater temperature rise with a carbide tip than with a ceramic tip, all other conditions being equal. Materials which require more power per cubic inch of metal removal per minute also cause correspondingly higher heat and temperature values in either tool material.

Milling with Ceramics

As was the case when carbides were first used in machine shops, initial efforts to obtain satisfactory performance with ceramics have, quite logically, been with single-point turning tools. The tests reported here follow the same approach. After ceramic tools had worked successfully on a lathe, a two-bladed, 6-in. diameter face-milling cutter was made to hold ceramic tips with cutting angles equivalent to those prevailing in the turning tests. Unfortunately, ceramics, which had shown superiority in turning certain ferrous metals, did not perform well in milling these same materials. Primarily because of the inherent interrupted nature of cutting in milling, the successful application of ceramics in milling is much more difficult than in turning. The mechanical strength of ceramic tips is usually reduced by repeated thermal shocks, such as those occurring in milling operations, in which the tool tip, during each cutter revolution, reaches a high temperature in the cut and then cools in the air. Alternating thermal and mechanical shock or impact limits the milling applications of present-day ceramics. The milling of plastics and light alloys and light finishing cuts on ferrous materials have been quite successful, since these involve reduced impact, smaller tool forces, and lower tool-tip temperatures. Milling test results with ferrous workpieces up to now do not compare favourably with the performance of ceramics in turning. Carbides have been superior to ceramics in milling cast iron and steel.

The milling cutter for these tests was designed in such a way that regular lathe tool shanks for so-called throw-away tips could be clamped into the cutter body. The

holding slots were arranged so that centrifugal force could not dislocate or release the tool holder. As a further safety measure a steel ring encircled the main cutter body to act as an additional restraint in retaining the tool shanks. Some of the ceramics tested were recommended for use at very high cutting speeds, making these precautions mandatory.

Conclusions

The experimental data on ceramic tool life in this report, although limited in scope, have proved of value in application to production tests. Much work remains to be done in evaluating ceramic tool life for other workpiece materials and in explaining the manner of failure in ceramic tools, which is different from that of carbides. A more consistent or uniform wear process in ceramics may result from further improvement in the material.

It has already been demonstrated that, for certain turning operations, ceramics are the best tool material. Up to now ceramics have not worked as well in milling operations as have other tool materials, but it can be anticipated that this situation undoubtedly will be improved in the future, as more experience and knowledge are acquired.

Attention once again must be focused on reducing the handling or load-and-idle time, which constitutes a major part of the production cost in machining with carbide tools and, with ceramic tools, may account for as much as 90% of the production cost of a machining operation. Although much remains to be learned about the technique of machining with ceramics, the great potential economic benefits to be derived from the use of these materials in many cases is evident, especially in the mass production of machined parts with special or automated equipment having extremely low values of non-cutting time. In essence, these economies stem from the greater metal-removal rates which are practical with ceramics and from the utilization of the concept of "throw-away" inserts, admirably suited to these non-strategic and relatively inexpensive materials. Such benefits have already been accomplished in isolated instances, and more widespread exploitation is inevitable.

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GERMANY

Hydrodynamic Shaft Seals

By W. Frössel. (From *Konstruktion*, Vol. 8, No. 11, November 1956, pp. 463–466, 6 illustrations.)

The problem of sealing the annular spaces between shafts and casings is not easy to solve satisfactorily, particularly for high-speed machines. This article describes a threaded shaft seal providing sealing by dynamic means, without wear and with minimum friction, as there is no direct contact between the stationary and rotating parts. Although primarily developed for liquids, this seal, fitted in a sleeve, is also suitable for gases.

Conventional sealing arrangements can be broadly classified as contact-pressure seals and labyrinth seals. For bearing housings, etc., where the main requirement is to prevent appreciable loss of lubricant, rings and oil-retaining grooves are reasonably effective. This simple arrangement, however, is no longer sufficient when the oil is splashed in all directions. In other applications, e.g., in turbines, blowers, and centrifugal pumps, the seals may be required to maintain fairly high differences in positive or negative pressure. These machines usually operate at high speeds, making the task more difficult.

The most common type of shaft seal is the stuffing box, with a wide variety of packing materials, although many new types of seals have been produced. All these constructions provide sealing by contact of a flexible material pressing on the rotating shaft. Their sealing action, therefore, is basically obtained by purely static means. At moderate speeds and with fairly true running conditions of the shaft and good surface smoothness, they fulfil their purpose satisfactorily, but a certain amount of friction must be accepted. At higher speeds, this friction results in considerable losses of power, and in heat generation and wear, thus limiting the life of the components.

For high peripheral shaft speeds, labyrinth types of seals are used in many applications. With these seals, a small leakage loss is deliberately accepted. The sealing action is obtained by enabling high flow velocities to be generated along fine clearances in the axial direction; the kinetic energy of the flow is then dissipated by sudden expansion, resulting in the formation of eddies in the annular chambers. There is a further pressure drop each time a flow velocity is generated, i.e., in each of the axial passages between these chambers. The overall pressure drop in the labyrinth arrangement provides nearly complete sealing over a relatively short distance. There is no contact between parts having relative motion but, against this advantage, is the necessity for allowing a certain amount of leakage.

In the course of research, the author investigated the possibilities and effectiveness of "threaded" types of shaft seals, which have a hydrodynamic action. There are various designs employed in practice, in the form of return screws and screw pumps. The investigation showed however, that in most cases there was no scientific concept of the manner in which these threads operate. Exploratory tests were therefore carried out; these indicated that the threaded shaft seal should be extremely effective, particularly at high and very high peripheral speeds, if correctly proportioned and suitably used. Further

knowledge in this direction, however, required a study of the conditions affecting the flow occurring in thread-type seals.

The basic design features of a threaded shaft seal are shown in Fig. 1. The thread is cut either in the housing (Fig. 1a) or in the shaft (Fig. 1b), and one of the two components has a smooth surface. There is no contact and therefore minimum friction and no wear between the shaft and its housing.

The hydrodynamic action of the seal is as follows:—The sealing fluid adheres to both moving and stationary surfaces and, when the shaft is rotating, the thread causes a spiral motion of the fluid and displaces it in the axial direction. In Figs. 1a and 1b, for instance, the displacement is from left to right, with the shaft rotation as shown. Sealing action is then obtained if the outside of the housing is on the left and the inside on the right. If these positions were reversed, the thread would act as a pump. Consequently, the simple type of threaded shaft seal can be employed only for one direction of rotation. However, it is conceivable that arrangements suitable for both directions of rotation may also be evolved.

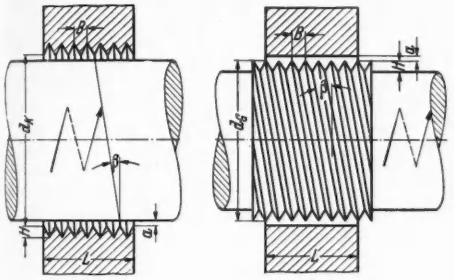


Fig. 1. **Basic types of threaded shaft seals, showing (a) the thread cut in the housing, and (b) the thread on the shaft.**

In the threaded shaft seal, there are two flow processes which are superimposed and balance one another. Firstly, owing to the higher internal pressure, the fluid to be sealed tends to be displaced axially outwards along the clearance a (Fig. 1) and also along the spiral paths of the threads; secondly, the fluid, as previously stated, is brought inwards by the screwing action against the internal pressure. As long as the delivery in the inward direction is greater than, or equal to, the outflow generated by the internal pressure, absolute tightness is ensured.

The hydraulic pressure obtainable in a threaded arrangement can be calculated by means of the equation*

$$p_i = \eta VLC/H^2 \quad .. \quad .. \quad (1)$$

where p_i = maximum attainable sealing pressure [kg/m²], η = viscosity of sealing fluid [kg-sec/m²], V = peripheral speed of shaft [m/sec], L = length of threaded seal [m], H = thread depth [m] and C = a coefficient. Eq. (1) shows that p_i is directly proportional to viscosity, so that this seal is primarily suitable for liquids. An arrangement introducing a liquid of higher viscosity in seals for thin liquids and gases will subsequently be described. The sealing pressure is also proportional to the peripheral speed V, indicating that it will be particularly effective at high speeds. The length L of the seal can be chosen to suit individual requirements. The coefficient C is mainly dependent on the ratio $(H/a)^2$, where a = radial clearance. Since a cannot be assigned an extremely small value, owing to manufacturing considerations and the need for ensuring reliability in operation, the thread depth H should also not be made too small. However, H^2 appears in the denominator of eq. (1) and has an inverse effect on p_i, so that H should not be made too large. For a complete determination of the coefficient C it would be necessary to establish the effects of various thread shapes, the size of the thread, and the helix angle β. It may be noted that C is zero for β = 0 deg. (annular grooves with zero delivery) and for β = 90 deg. (recesses parallel to axis), so that it must reach a maximum at some intermediate angle.

In view of the complex conditions of motion of the fluid in the thread, a theoretical treatment will not be given in this article. However, a qualitative assessment can be obtained by means of the data presented in Table I.

TABLE I: Values of Coefficients C.

	Helix angle β							
	0°	5°	10°	12°	15°	20°	25°	90°
Metric thread, with pitch B = 1 mm, H = 0·7 mm, H/a = 14	0	14	25	27	24	16	11	0
Metric thread, with B = 0·5 mm, H = 0·3 mm, H/a = 6	0	3	5	6	7	7	6	0

These values of $C = p_i/(\eta VL/H^2)$ indicate in a non-dimensional form the pressures p_i obtained experimentally for two types of metric threads used for the shaft seals investigated. In general, the maximum C-value is situated between 7 and 25 deg. The radial clearance a should not be less than, say, 0·05 mm, and it has already been mentioned that sealing is more effective with small clearances. Furthermore, it can be recommended that shaft seals be made preferably of bronze, which will eliminate the danger of seizure, in case of contact.

The number of threads was varied from 5 to 40 for the 1-mm thread, and from 10 to 80 for the 0·5-mm thread. In the design stage, the helix angle β can be determined from

$$\tan \beta = mB/(\pi d_k) \quad .. \quad .. \quad (2)$$

where m = number of threads, B = pitch, and d_k = minor diameter of thread. It is necessary to make m a whole number, and to use the corresponding value of β evaluated to three significant figures; however, β should of course, have a value in the range giving maximum C-values, as indicated above.

Systematic tests to determine these results were carried out on a shaft of 40 mm diameter, which was run successively at speeds of 100, 200, 500, 1000, and 2000 rpm. Tests at higher speeds will be made in due course. The C-values in Table I were based on tests of metric threads, using four helix angles for each thread size. With increasing values of H/a, the peak of the C-curve evidently tends towards smaller angles β. Further tests, however, will be required to confirm this conclusion and to show whether curves with the same H/a ratio, but having different H- and a-values, coincide.

While these results may not suffice for a complete investigation, they nevertheless give sufficient data for practical purposes, as regards suitable size of thread, helix angle, permissible clearance, and expected value of sealing pressure.

For design work, graphs based on the tabulated values given above can be used. Thus, if H/a = 14, a = 0·05 mm, H = 0·7 mm, and B = 1 mm, the optimum values are

* GÜMBEL EVERLING: "Reibung und Schmierung im Maschinenbau," M. Krayn-Verlag, Berlin, 1925.

$\beta = 12$ deg. and $C = 26$. For different H/a ratios, other optimum C-values may be obtained by interpolation. The C-value can then be substituted in eq. (1) to evaluate p_i.

To give an idea of the sealing pressures approximately attainable, it is convenient to consider as an example a shaft of diameter $d = 0{\cdot}1$ m, running at 3000 rpm. The shaft seal is chosen with a length $L = 0{\cdot}05$ m for the threaded section, and the sealing fluid (spindle oil) has a viscosity $\eta = 0{\cdot}001$ kg-sec/m^2 at 60°C. With these values, eq. (1) gives a sealing pressure of 4·2 kg/cm^2. It should be borne in mind that oil viscosity decreases rapidly with increasing temperature, so that the sealing pressure is correspondingly reduced. Although the seal operates with very little friction, it heats up somewhat because the sealing liquid in the thread is not replaced to any appreciable extent. Where necessary, therefore, the housing should be provided with cooling arrangements. With fluids of high viscosity, considerably higher sealing pressures can be obtained.

In many applications the main requirement is frequently only that of preventing oil spray, oil foam, oil accumulations, etc., with very little pressure. For such applications a short threaded shaft seal is generally sufficient.

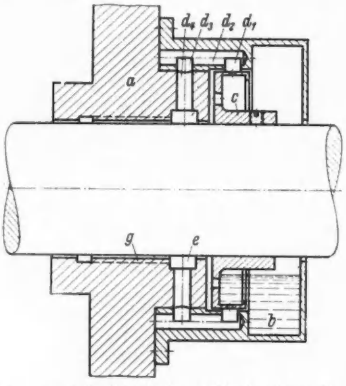


Fig. 2. **Arrangement for introducing a high-viscosity sealing fluid for gases or vapours.**

For gases or vapours, as in the case of blowers and steam turbines, a sealing fluid with a suitably high viscosity must be interposed. Fig. 2 shows an arrangement evolved for such installations. The housing a is provided with an internal thread g forming the sealing section. The thrower c, partly immersed in the sealing fluid in space b, continuously supplies fluid through annular groove d_1, passage d_2, groove d_3, and passage d_4 to the annular groove e, which is thus kept completely filled. The threaded seal, therefore, is in contact only with the sealing fluid and generates a corresponding sealing pressure which acts against the gas pressure inside the machine. When the gas pressure is increased, the sealing fluid is forced further into the threaded seal and thereby increases the sealing pressure, which adapts itself automatically to the internal pressure of the gas. Leakage fluid is collected in space b, so that there is no consumption of fluid. The sealing fluid does not need to have any lubricating properties, the only requirements being that the viscosity/temperature characteristic should be as flat as possible, and that the fluid should not react with the medium to be sealed.

The threaded shaft seal operates only when the shaft rotates. If sealing is also required in the stationary condition, an additional static arrangement, capable of engaging and disengaging itself automatically, will be necessary. Various solutions are possible. Fig. 3 shows as an example a patented arrangement which operates by means of centrifugal action. The lip-type seal a, which provides a tight joint when the shaft is stationary, disengages from the stationary wall b of the housing as centrifugal force increases, by which time the threaded shaft seal should become sufficiently effective to provide dynamic sealing.

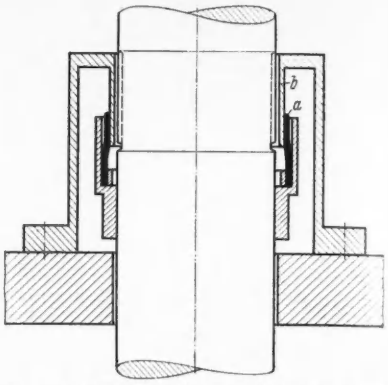


Fig. 3. **Combined static and dynamic shaft-sealing system.**

The "Multiplex" Electric Railway System

(*Concluded from page 6*)

tions, without the need for shunting at termini, and makes it possible to keep to time-tables, independently of the number of coaches in the train.

(2) Tractive power and weight are evenly distributed over all axles of the train.

(3) The use of small motor units lowers the floor level and reduces the structural weight of the coaches, with a consequent reduction in power consumption.

(4) Electric d.c. braking is fully exploited, resulting in increased safety on single-phase railways and considerably reduced wear and tear of mechanical brakes.

(5) Construction is simpler than it is in any other comparable train, including underground trains, and the driving motors are better protected against flash-over voltages from the overhead line.

(6) There is less wear and tear on the overhead line than with any other type of electric train. Furthermore, the possibility of causing the overhead line to swing from the effect of several pantographs is eliminated. In addition, when the train is stationary, the Multiplex feeder is dead.

(7) In the Multiplex train, passenger coaches can be supplied with current for heating and lighting from the pantograph coach, and also with compressed air for the mechanical brake.

(8) The Multiplex train can be adapted to every form of passenger traffic, using standardized bogies, motors, and ancillary equipment. Moreover, it meets the requirement for high average speeds in local traffic, as well as high maximum speed in long-distance traffic.

(9) The Multiplex train can be designed for frequencies of $16\frac{2}{3}$ cps, as well as for the frequency of the normal power-supply system, e.g., 50 cps.

Metal Whiskers

By G. W. SEARS and S. S. BRENNER. (From *Metal Progress*, Vol. 70, No. 5, November 1956, pp. 85–89, 8 illustrations.)

Tests on small metal whiskers show that their strength is close to the theoretical value ; thus, for example, the tensile strength of an iron whisker was found to be 1,900,000 psi. Unfortunately, however, the strength decreases with increase in size, although many of the other unusual properties of metal whiskers are retained.

IN recent tensile tests on pure annealed iron, a specimen withstood 1,900,000 psi before fracture. Equally remarkable by comparison with the behaviour of ordinary tensile specimens was the absence of plastic deformation and work hardening. The test was performed on an iron whisker 4×10^{-9} sq in. in cross-section and 0·1 in. in length. The applied load, which was only 0·1 oz, produced an elastic strain of almost 5%. The test clearly showed that the elastic strengths calculated for perfect crystals can be attained for actual crystals.

With the development of increasingly compact electronic units, a surprising difficulty has arisen, involving the growth of very fine whiskers of tin or cadmium from the protective plating on components, resulting in putting the equipment out of operation when the whiskers act as short-circuits. Galt and Herring reasoned that tin whiskers might be free from dislocations by virtue of their small size, and in 1952 they demonstrated that tin whiskers can support elastic strains in bending of about 2%. This was the first example of crystals which exhibited the elastic behaviour postulated for perfect crystals. Since then, a large variety of metal whiskers has been grown by several methods. The tremendous strength of some of these whiskers has been demonstrated even more strikingly by recent tensile tests in which the stress on the whiskers was much higher than in a bend test. The strength of 1,900,000 psi for iron is believed to be the highest tensile stress ever supported by metal. Maximum tensile strengths reported for other metallic whiskers are 555,000 psi for silicon, 440,000 for copper, 250,000 for silver, and 55,000 for zinc.

The tensile tests on iron, copper, and silver were carried out in a special apparatus in which the whisker, mounted at one end to a float containing a magnet, was stressed by applying a current to a solenoid which pulled the float towards the centre of the solenoid. The force exerted by the solenoid was calibrated with the aid of a balance. In a few instances, the strain, as well as the stress, was measured by observing the change in distance between two fiducial marks on the whisker. The stress-strain diagram of a superstrong iron whisker is shown in Fig. 1. The whisker was about 0.00006 in. in diameter and 0·1 in. in length. The strain, reported to be entirely elastic, is proportional to the stress only up to 2%. When the whisker finally fractured after having been stretched close to 5% of its original length, sufficient elastic energy was released to cause it to snap back and wrap itself around, as shown in Fig. 2.

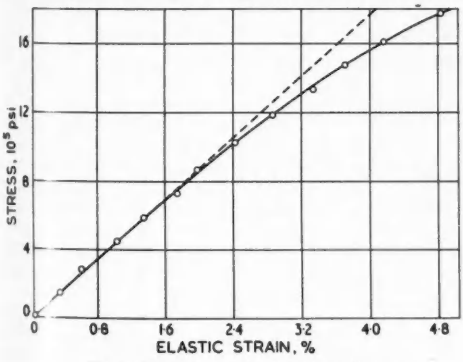


Fig. 1. Stress-strain curve of an iron whisker.

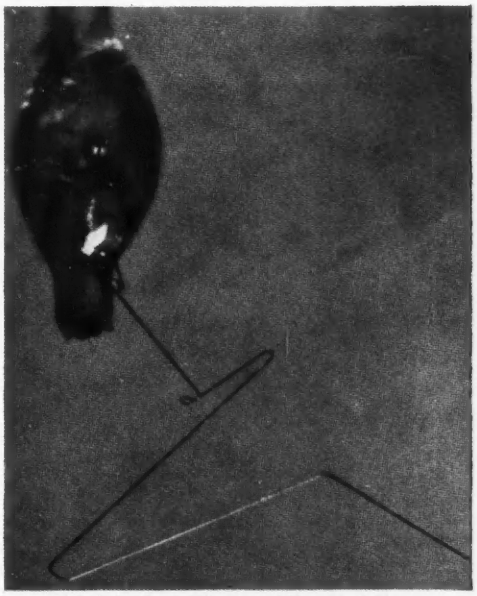


Fig. 2. Appearance of an iron whisker after fracture.

Whiskers can be obtained in a number of ways. The tin whiskers used by Galt and Herring, as well as zinc and cadmium whiskers, grow spontaneously at room temperature from coatings of these metals. The coatings can be applied by electrodeposition, vapour deposition, or hot dipping. The spontaneous growth of the whiskers requires several weeks or months, but can be accelerated as much as 10,000 times by the application of pressure to the coating. The whiskers, about 0·00001 in. in diameter, grow by the addition of material at their base and attain lengths up to ½ in. In addition to straight whiskers, many are bent and kinked.

Another method of growing whiskers is the condensation of supersaturated metal vapour at a suitable temperature. The first metal grown in the shape of whiskers by this method was mercury which had been evaporated at −22°F and condensed on a pyrex surface at −81·4°F. Zinc whiskers grown by this method at 660°F, and silicon whiskers at 2280°F, sometimes attain lengths in excess of ½ in. One silicon whisker grown by condensation supported a bending stress of 725,000 psi.

A third method of whisker growth is the chemical reduction of metal salts such as the halides. The halide

vapour or a boat filled with the solid halide is brought into the hot furnace where it decomposes or is reduced by hydrogen or zinc. Iron whiskers grown by this method are shown in Fig. 3, in which it will be noted that some are twisted and kinked. A large variety of whiskers has been grown by this method. Whereas iron, copper, silver, and silicon whiskers grow in great profusion, the number of gold and nickel whiskers is very small. Copper whiskers appear to grow by the addition of material at their tips.

A fourth method of whisker growth is electrodeposition. Most work on the growth of metals such as silver or copper in the form of thin single-crystal filaments has been effected by German and Russian workers. It has been found that the use of very small cathodes, high current densities, and inhibitors such as gelatin or dextrose promote the filamentary growth. Very little has been reported concerning the size and properties of the filaments or whiskers.

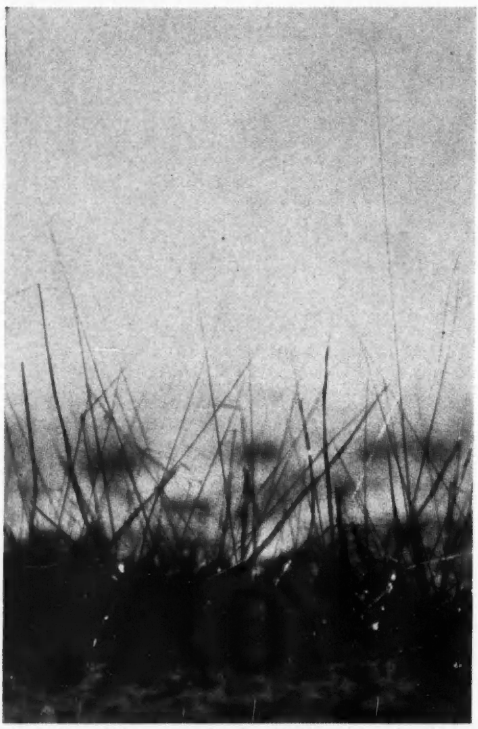


Fig. 3. Iron whiskers grown by the reduction of iron bromide at 1330°F. (×8)

It has been possible to elaborate a detailed growth mechanism for the direct vapour-deposition process. In 1878, Gibbs postulated that growth of a perfect crystal could only occur by a mechanism of two-dimensional nucleation. He pointed out that growth could occur at an appreciable rate for supersaturations above a critical value. In 1931, Volmer and Schultze measured the growth rate versus supersaturation for several crystals, and found that growth continued almost to zero supersaturation. The discrepancy between the experimental results and Gibbs's prediction was resolved by Frank in 1949. Frank commented that, since real crystals are imperfect, repeated surface nucleation as proposed by Gibbs may not be necessary for continued growth. He proposed that the intersection of a screw dislocation with the surface created a permanent step on the surface at which growth could proceed. As growth occurred the step would rotate around the fixed screw axis and generate a spiral growth marking. Growth by the screw dislocation could occur at very low supersaturations, in agreement with the results of Volmer and Schultze.

To account for the whisker growth from the vapour phase, it is sufficient to assume a parent crystallite having a single screw dislocation. At low supersaturations such a crystallite should grow in the direction of the screw axis at constant cross-section. The growth by this mechanism proceeds by a tip-growth process. The resultant whisker bears a single-axial screw dislocation and should have the theoretical elastic strength.

Of the other processes which have been used to produce whiskers, it is possible to make a basic differentiation. Any basal growth process, such as the growth of tin whiskers spontaneously or by application of pressure, patently cannot occur by the growth mechanism proposed for vapour deposition. If growth occurs at the tip, as in copper whiskers prepared by chemical reduction, the uniaxial screw mechanism may offer a reasonable explanation of the growth behaviour.

Most of the short straight whiskers are single crystals with their axes parallel to a major crystallographic direction such as [111], [110], and [100]. Some of the kinks in the distorted whiskers appear to be twins. The cross-sections of the whiskers are usually polygonal. There is, however, considerable variation in the cross-sectional shape of whiskers of the same metal. Heating at temperatures near the melting point causes the whisker edges to become rounded. Many of the whiskers have highly reflective surfaces, some of which appear perfectly smooth at magnifications as high as ×40,000.

Spectrographic analyses of copper whiskers have indicated the presence of silver in a concentration of about 30 ppm. The concentrations of other elements commonly encountered in copper were below the sensitivity of the spectrograph. Purification of the salt prior to its reduction reduced the silver content in the whiskers below a detectable amount. The purity of other metal whiskers has not been established.

At present, the mechanical properties of whiskers are of greatest interest, but there are indications that whiskers may possess other properties quite as remarkable. For instance, if a copper whisker is bent beyond the elastic limit until permanent deformation occurs, the whisker will recover its original shape if subsequently annealed at a high temperature. A copper whisker which was straight initially was bent until it kinked, and then annealed at 1855°F. It recovered its original shape after 40 min. The deformation and the subsequent anneal did not impair its strength.

Although the mechanism of deformation or kinking of a whisker is not yet understood, it seems reasonable to assume that edge dislocations are introduced into the whisker when the elastic limit is exceeded. The high-temperature recovery of the copper whisker implies that these dislocations can again migrate out of the crystal at sufficiently high temperatures. The migration is presumably possible because of the absence or near-absence of dislocations in the original whisker. In bulk crystals, the thermal motion of dislocations is hindered by the interlocking of the dislocations.

The transformation of the iron whiskers from alpha to the gamma phase is another interesting phenomenon, this transformation being, accompanied by severe dis-

tortion of the whisker. Transformation occurs at intervals along the whiskers, and the boundary of the alpha region can sometimes be observed to travel along the whisker. It is characteristic of a nucleation and growth process. The nucleation of the gamma phase is assumed to be more difficult in the whiskers because of the absence of dislocations. Superheating of the alpha phase is frequently required to initiate the transformation in a reasonable time. The distortion which occurs upon transformation is probably due to the volume change of the two phases.

One of the greatest hindrances to many applications is the extremely small size of the whiskers. Although they can be grown several inches long and 0·010 in. thick, the larger whiskers are much weaker than the finer whiskers. The decrease in strength is believed to be due to the accidental formation of structural defects as the whisker grows. A major problem is to find means of preventing the formation of these defects, either by modifying existing growth techniques or by developing new techniques.

The research applications of whiskers are numerous, and several practical applications may result from them. For instance, whiskers may become useful in experiments requiring relatively pure single crystals of known orientations. The preparation of single crystals by ordinary techniques, especially of iron, is considerably more difficult.

The field of magnetism will undoubtedly benefit greatly from studies on iron whiskers. The orientation of most of the iron whiskers is such that their axes are parallel to the direction of easy magnetization. They are small enough to contain only a few domains, and it may be possible to study the motion of domain walls as the magnetic field is reversed.

Experiments making use of the great strength of the whiskers may produce interesting results. Several per cent of elastic strain has a profound effect on the metal lattice, changing its crystallographic symmetry and probably affecting its electrical resistance, magnetic properties, and chemical properties. If whiskers are free of dislocations they may be useful in studies involving diffusion, phase transformation, precipitation, and other kinetic processes which are greatly influenced by structural defects. The residual resistivity at low temperatures due to defects may be determinable by using whiskers.

Surface reactions such as adsorption, evaporation, and catalysis are greatly influenced by surface structure and smoothness. The surfaces of whiskers may be perfect and atomically smooth, so that these reactions may be considerably altered.

The discovery of whiskers has demonstrated that the theoretically calculated strengths for perfect crystals may actually be attained. Future studies will undoubtedly extend understanding of solid-state behaviour.

RUSSIA

Pressure Diecasting of Steel

By P. N. Bidulya, I. I. Bobrov, and K. N. Smirnova. (From *Liteinoye Proizvodstvo*, No. 7, July 1956, pp. 1–4, 15 illustrations.)

Efforts to produce steel castings of arbitrary shape under pressure in a die have been pursued for some time. Diecastings in steel were first produced in Russia in 1943 under a pressure of 0·2 to 0·3 kg/mm^2, operative during the crystallization period in the transition from the liquid to the solid state, the steel being melted in a side-blown converter, whence it was fed to the hydraulic press. However, with such a relatively low pressure the castings produced had the flaws characteristic of cast metal. The formation of a crust and of gas occlusions was observed on the surface of the liquid metal poured into the die, the thickness of the component was excessive, and the flash between the two halves of the die contained cracks. These results indicated the need for increasing the specific pressure, and since 1949 investigations were initiated with this object in view, and have yielded many important results in the study of this production process and of the properties of components so produced.

Compared with dies for cold and hot stamping operations, those for diecasting under pressure possess certain peculiarities. The vertical clearance between the moving parts of the die must be reduced to a minimum, because the liquid metal entering the clearance space solidifies almost immediately, thereby tending to jam the sliding components, interfering with the opening of the die halves, and rendering them unserviceable after a single cast. In addition, the pressure exerted on the metal cannot be removed before the end of crystallization, as in the case of the conventional diecasting process ; otherwise, the components produced exhibit discontinuities formed during shrinkage. If the metal is fully crystallized under pressure, completely dense components can be obtained under certain conditions, without the use of the risers customary in steel castings.

To eject the finished component from the punch, the die must include an ejector of special design. During pressing, if the joints between the die and the punch are not absolutely tight, the liquid steel can penetrate these joints, and hence a special packing must be included in the die. After numerous experiments, an improved design of die was developed. This design is illustrated in Fig. 1, which shows the die in the open position, ready to receive the liquid steel. A die (1), secured by a clamp (7), forms the cavity into which the steel is poured. In the lower central part an opening is made, through which a spring-loaded ejector pin passes. A metal-retaining ring (2) forms the side walls of the vessel for the molten metal, the upper edge of this ring being fitted with a projection which enters into a groove turned in a separator ring (3). When the punch (4) is lowered, the separator ring (3) is pressed against the metal-retaining ring (2), making a tight joint. The retaining ring (2), together with the die (1), gives a vertical clearance of about 0·5 mm per side, and metal cannot enter this clearance because, before the application of pressure, a solid crust of steel, with a thickness of 3 mm, is formed at the bottom of the die. The tightness of the seal between rings (2) and (3) is an essential condition for successful operation, and is achieved by accurate facing of the horizontal surfaces and by ensuring the concentricity of the tapered spigot and the groove. To guard against jamming of the die, the metal-retaining ring (2) is split into two halves, joined together by a wedge, which

is loosened when the two halves are clamped together. The separator ring (3) is suspended on the punch (4) by means of a separating lever and, together with the punch, has a reciprocating motion. The punch produces the shape of the upper half of the component and is provided with holes of about 0·2 mm in diameter for the removal of gases.

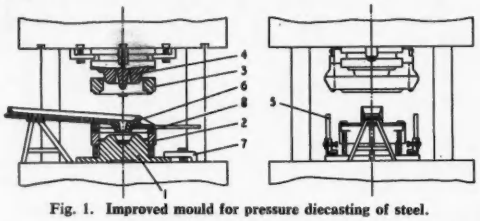


Fig. 1. Improved mould for pressure diecasting of steel.

A jacket (8) and a feed channel (6) rest loosely on the die, and are removed after pouring. The punch (4), backed by the working pressure of the hydraulic press, is then lowered until the separator ring (3) touches the metal-retaining ring (2). With further lowering of the ram, ring (2) starts to compress the supporting springs, sliding down along the die, and the punch penetrates into the metal, the whole die at this point constituting a totally enclosed vessel. As compression continues, the liquid metal fills all the voids in the mould and assumes its shape exactly ; after full compression (about 8 kg/mm²) has been reached, the clamps (5) engage the projections in the separator ring (3). After completion of crystallization (10 seconds or more), the press is switched over for the ram-lifting operation. The punch (4) is first withdrawn from the component, whilst the separator ring (3) remains held in position by the clamps (5). With further lifting of the punch, these clamps exert a pull on ring (3), separating it from the component. As the lifting motion is continued, the clamps (5) are disengaged from the projections of ring (3), and the supporting springs lift ring (2), after which the finished component is ejected from the open die by the ejector and the die is ready for another cycle.

This design of die has been found to satisfy all production requirements, and the components so obtained differ from those manufactured by hot stamping, conventional casting, or even pressure diecasting. When comparing hot-stamping and casting methods with the new method, involving pressing from liquid metal and crystallization under a high specific pressure of about 8 kg/mm², it should be pointed out that, with the latter method, the large allowances required for the removal of casting skin and for the machining of stamped components are eliminated, together with the wastage of metal incurred by runners and risers. The weight of the finished blanks may attain 90 or even 95% of the weight of the molten metal—a figure impossible with either hot stamping or conventional casting. Furthermore, comparisons of the labour required to produce a solid component, such as a wheel, by existing methods and by the new method show that, with the latter, direct labour is reduced by a factor of 5·5.

The main parameter which characterizes the pressing of liquid steel in the process of primary crystallization is that of the specific pressure on the metal in the die. As a starting point, it was assumed that the optimum pressure must not be less than 5 kg/mm², referred to the working surface of the die, and that, in order to obtain a dense steel structure, it was essential not to exceed a certain thickness of component. This means that the pressing of massive bodies like ingots in a chill mould cannot be as effective as that of relatively flat components like wheels. It was therefore decided to select certain typical components for experiment, including a cylinder of 56 mm diameter and a variable length between 10 and 85 mm, rectangular plates of up to 30 kg weight, horizontally located in the die mould, and shaped components such as rollers, wheels, and gear blanks. The steel for these experimental components was prepared either in an induction furnace with a 35-kg charge or in an acid Bessemer converter. The components produced were assessed by the condition of their external surface and by the micro- and macro-structure throughout the volume of the component, the density and mechanical properties of which were also measured.

In the experiments so far conducted, after several unsuccessful attempts to use alloy steel for the die, the best results were obtained with an 0·2% carbon steel. However, the extent of the tests does not justify forming final conclusions, which can be reached only after extensive production tests.

A component surface of good commercial quality can be obtained when the appropriate conditions for pouring the metal are observed. These include heating the mould to between 150 and 200°C, and the correct pouring temperature of the steel, depending on the particular steel used. When the pouring temperature is too low and when the mould is insufficiently heated, a characteristic " creased " surface was noted.

The duration of holding the pressure on the metal in the die must be a minimum, limited by the primary crystallization stage. In this connection, observations have shown that a period of 20 sec was sufficient for the complete crystallization of a hub casting weighing 20 kg, the temperature dropping to between 900 and 1050°C after this period had elapsed. With a shorter holding time, e.g., 10 to 12 sec, breaking up of the not yet solidified component was observed after removal of the punch from the die. In the case of a gear blank weighing 1·5 kg, the duration of pressure was about 10 to 12 sec.

Examination of the macro-structure of polished sections of pressure and conventional castings was also carried out ; it was found that a slab of 75 × 120 × 315 mm, cast in an open mould, had a characteristic shrinkage crater and a needle structure, while a similar slab, cast under a pressure of 8 kg/mm², showed a fine grain structure, with complete absence of the shrinkage crater. A few pin-sized gas occlusions were, however, noted. In perfect specimens produced by the pressure-casting process, it was found impossible to discover any macro-structure, while the micro-structure proved to have a pronounced fine grain.

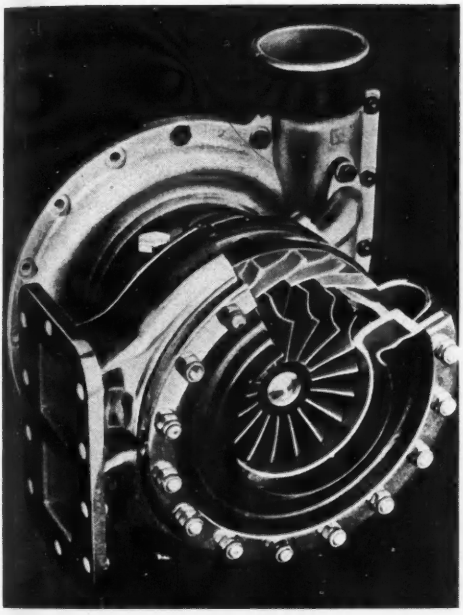
Extensive investigations dealing with precise measurements of density throughout the volume of castings and pressings were based on a method which ensured a maximum error of 0·02 gm/cm³. It was established that variations in density ceased at a pressure of 5 kg/mm², and on this basis the minimum pressure for sound castings was considered to be in excess of this amount.

The mechanical properties of cast components were determined for a range of carbon steels and were compared with those of the same type of steel in rolled form. It was found that, after normalizing, the pressed-steel specimen showed greater strength and ductility than either cast steel or rolled steel of the same type. In medium-carbon steels the superiority in quality was still more pronounced, even without normalizing, but with steels of higher carbon content normalizing was once again necessary.

British Industrial Developments

Turbocharger for High-Speed Diesel Engines

It is announced by Simms Motor Units Ltd., of London, N.2, that they have acquired the exclusive licence to manufacture and sell in the U.K. and throughout the sterling area the turbocharger developed by Gerätebau Eberspacher, of Esslingen, Germany. Production is scheduled to begin in early 1957, and the turbocharger units, which have been produced primarily for use on road-vehicle engines and which can easily be adapted to the majority of high-speed diesels, will be made at the Simms factory in East Finchley.



The essentials of the successful turbocharging of vehicle engines is that the equipment used must be small in bulk, that it must involve a minimum of alteration to the standard engine, and that it must be quiet in operation. Furthermore, no modification to the routine maintenance of the power unit of the vehicle should be incurred. The Simms-Eberspacher turbocharger fulfils all these requirements. Weighing only 37½ lb and with an overall diameter of 11 in. and a length of 9 $\frac{9}{16}$ in., it is exceptionally easy to install, all the more so because no positive drive from the engine has to be provided, the only alterations to a standard engine being slight rearrangements of air and exhaust piping. Furthermore, the design of the supercharging impeller, which is the major source of noise in any turbocharger, is such that the noise level is reduced to an acceptable minimum.

Basically, the unit is a high-speed supercharging blower driven by a gas turbine which is, in turn, driven by the exhaust gases from the engine. The maximum permissible speed is 38,000 rpm and the maximum permissible gas inlet temperature is 1256°F. The unit is extremely adaptable to all conversions and can be operated independently from the engine, insofar as lubrication and cooling are concerned, so that it can be fitted in any desired position on the vehicle. An interesting feature is that it is available as a completely water-cooled unit, a completely air-cooled unit, or as a partially air- and partially water-cooled unit. The basic unit, with appropriate variations in types of nozzle rings, rotors, and gas inlet pieces, can be made to serve a variety of engine sizes. In this connection, the standard model can be made to suit engines ranging from 75 to 200 bhp, normally aspirated.

Operational results from units actually in service indicate that reductions in specific fuel consumption up to 9% are being obtained, that torque characteristics are meeting the most stringent requirements, and that, owing to the extreme lightness of the rotor assembly (2·2 lb), the speed of the turbocharger responds extremely quickly to that of the engine.

Aerosol-Packed Silicone-Spray Mould Lubricant

The first all-British aerosol-packed silicone-spray mould lubricant is now being produced by Amber Oils Ltd., of London, W.1. Designated "Ambersil", the new product is based on a well-proved silicone fluid which, if used without a carrier, would prove to be too expensive for most industrial applications. In order, therefore, to obtain the thinnest possible coating and hence the most economical outlay, the fluid is applied as a spray under the pressure of the propellant in an aerosol dispenser, making it particularly easy to use. Products similar to Ambersil have already achieved considerable success in the U.S.A., but have hitherto been practically unobtainable in Great Britain.

Ambersil is produced in two formulae. Of these, formula 1 comprises a pure methyl silicone fluid, with high lubricity, high heat resistance (flash-point = 600°F), and low surface tension. In addition, it is colourless, odourless, non-toxic, non-volatile, water-repellent, chemically inert, highly resistant to oxidation and shear breakdown, and virtually non-inflammable, the spontaneous ignition temperature being of the order of 900°F. Formula 2 consists of a similar silicone fluid diluted with an appropriate solvent, giving an even finer spray and a thinner film on the mould surface. Its use, however, should be restricted to moulding operations at the lower temperatures.

Although Ambersil is particularly suitable as a mould release agent for almost all plastics, including thermoplastic and thermosetting materials, laminating resins, synthetic rubber, and other high polymers, it has many other applications in a wide range of industries. Thus, for example, formula 2 can be used successfully in zinc-alloy and aluminium diecasting, giving a greatly improved finish and lower cycle times than conventional methods. In rubber manufacture, formula 2 is recommended for cold moulding, bead and parting-line release in tyre production, and also as a lubricant for hose mandrels and extrusion dies. Similarly, in baking, packaging, and printing operations, formula 1 is an excellent anti-stick coating, while, in welding, a preliminary application of Ambersil to areas adjoining the weld can prevent weld splatter from sticking, and makes slag and splash easy to scrape off.

As a general-purpose lubricant, the low surface tension of Ambersil permits it to coat and lubricate highly finished surfaces to which conventional oils cannot adhere. Its viscosity is stable at all usual temperatures and it contains no volatile fractions, so that it is an excellent lubricant for office machinery, plastic-to-metal gears, ventilators, conveyors, etc.

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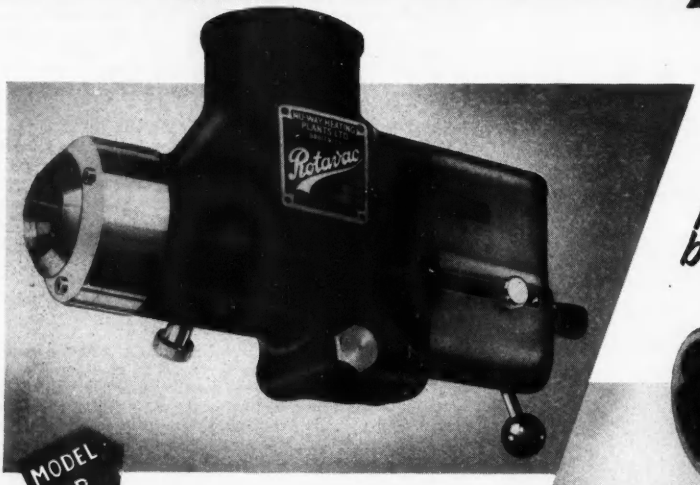

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Production of Tapered Roller Bearings

As the largest manufacturers of tapered roller bearings in Europe, it is hardly surprising that the policy of British Timken Limited is to continue the development of production techniques to enable workers to produce more in a shorter time with no extra effort. That this policy has been put into practice is only too clearly evidenced by the character of their factories at Daventry and Duston, Northampton. The larger bearings, weighing up to 4½ tons and up to 10 ft in diameter, are produced at Daventry, while smaller bearings, including precision bearings for machine tools, are made at Duston. The output from these factories is used in a wide range of industries, including the automotive industry, bakery and restaurant machinery, compressors, rolling mills, engines, locomotives, marine equipment, farm machinery, household appliances, and machine tools.

Although tapered roller bearings have been used as important components in machine tools for many years, it is only in the last twenty years or so that their use has become widely recognized. Bearing requirements for machine tools are varied but, for convenience, may be divided into two main groups. The requirements for the first group, covering bearings for pumps, controls, drives, and gear shafts generally, can be met from the standard Timken range. Requirements for the second group, dealing with work and cutter spindles, including grinding spindles, are generally covered by bearings from the precision ranges, i.e., the Timken precision "3" bearing, for which the maximum run-out of either the cup or the cone does not exceed 0·0003 in.; the precision "0" bearing, 0·00015 in.; and the precision "00" bearing,

Fig. 1.

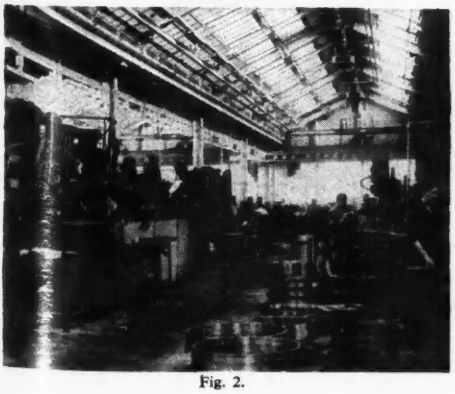

Fig. 2.

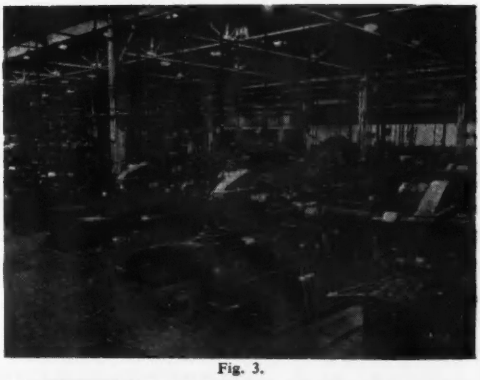

Fig. 3.

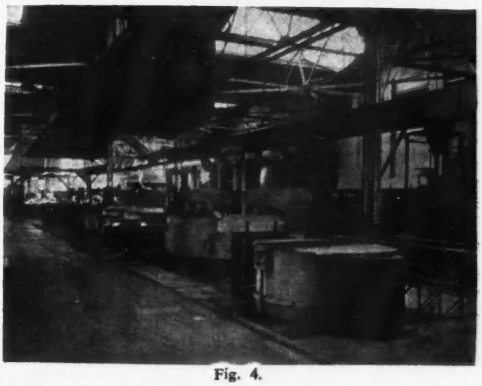

Fig. 4.

0·000075 in. Although the standard bearings are themselves made to high precision, the three ranges of precision bearings are made by highly skilled operators in a special department with equipment more suited to the close tolerances required. To obtain the maximum efficiency from bearings, all inaccuracies of each bearing are noted and are recorded in the bearing box. The high points of run-outs of these bearings are also marked, thereby enabling the user to set them up in such a way that even small inevitable inaccuracies are reduced to a minimum when the bearings are set up correctly.

An outstanding feature of the Timken factories is the extraordinary degree of cleanliness prevailing. Figs. 1 and 2 show respectively part of the grinding and machine shops at Daventry, in which this feature is clearly evident, while views of part of the grinding and hardening shops at Duston are given in Figs. 3 and 4. Another interesting feature is that of "tagging" every machine tool with a price label, thereby having the salutary effect of forcibly bringing home to their operators some concept of the value of the equipment they handle.

Large-Capacity Projection Pantometer

An extension to the range of instruments manufactured by Optical Measuring Tools Ltd., of Maidenhead, for the inspection of turbine blades is their new large-capacity projection pantometer (Fig. 1), which has been developed to provide for the inspection of blades up to 24 in. in length and 6 in. chordal width, with a permissible thickness of 2 in. Provision is also made for checking the contour and size of any predetermined section, and also section displacement and twist.

The principle used in the contour and size check is

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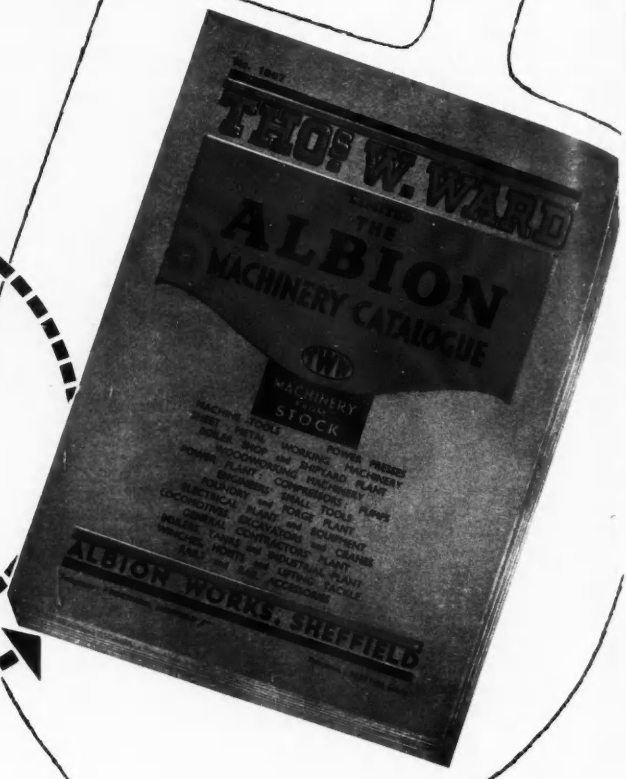

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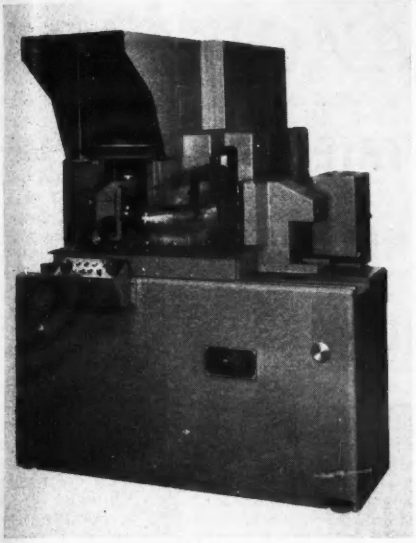


Fig. 1.

that of a stylus follower with optical reproduction of its path, as already employed in the standard and model "E" pantometers. The blade is mounted horizontally on the instrument table by means of a work-head, or headstock, which has co-ordinate movements in the vertical and horizontal planes and rotational movement about the horizontal axis, each of these co-ordinate movements being actuated by micrometers. Two diametrically opposed styli are mounted on slides, and each is thereby connected to an objective lens. Mounted beside the screen unit, in such a manner that it rotates through the vertical plane, is a disc containing separate graticules of each blade section to be checked. The graticules are so arranged that light from the lighting unit passes through the graticule and objective lens and is transmitted to the screen, where any observed image is at $\times 30$ magnification. The screen, which measures 16 $\times$ 16 in., contains a tolerance graticule in the form of concentric circles, the mean circle representing the diameter of the stylus at $\times 30$ magnification and the others representing permissible tolerances. As the stylus traverses the blade contour, its objective lens follows an identical path and projects the relevant part of the graticule to the screen ; thus, the image of the graticule is observed to pass across the screen and, if the blade is correct, through the tolerance zone. A detail of the work-holder, with a blade in position, is shown in Fig. 2.

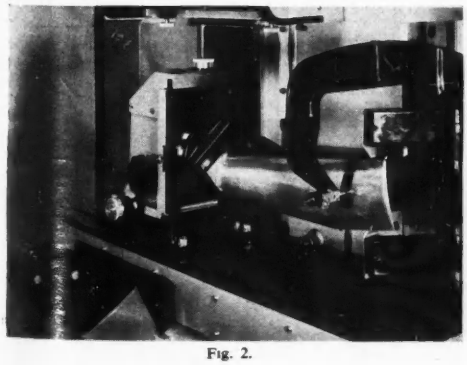
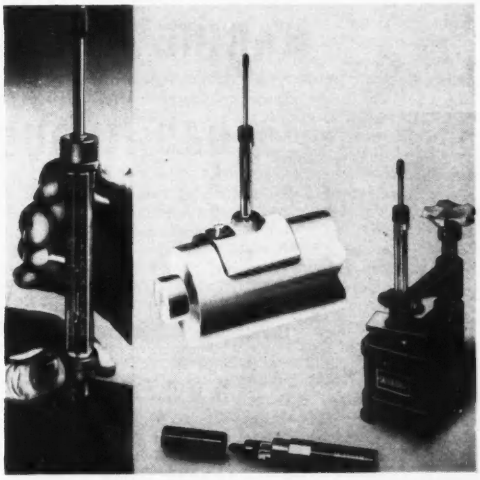


Fig. 2.

In addition to the stylus carriages, there are two positional indicators mounted on ball slides, and any displacement of section, or twist, is indicated by two " spot " graticules associated with the indicators. A setting plug is used to establish the correct position of the indicators, after which they are brought into contact with the leading and trailing edges of the blade, and any deviation is shown by the displacement of the spots on a small screen immediately below the main screen. Should there be no error, both spots should coincide with the centre of the cross-lines but, if an error is present, this can be compensated for and measured by means of the micrometers on the work-holding head. The principal operational movements are power-controlled, and the table traverse, the graticule location, the stylus travel, and the positional indicators are all operated by push-buttons.

Pocket-Size Hardness Tester

Stated to be the smallest yet made, the " Sklerograf " pocket-size hardness tester, manufactured in Germany by Roell & Korthaus, of Solingen, and exclusively distributed in the U.K. by C. Tennant, Sons & Co. Ltd. of London, E.C.2, operates on the rebound principle and combines simplicity of operation with consistently reliable test results.



In use, the " Sklerograf ", which has been specifically designed for on-the-spot testing, is placed in a vertical position on top of the specimen to be tested, as shown on the left of the illustration, and a rebounding bar, which carries a hardened-steel ball point, is raised until it is held in place by a locking device. When the locking device is released by pressing a catch, the bar falls, rebounding to a point corresponding to the hardness of the object and being retained at this point. Hardness can then be read to within one point Rockwell C by noting the position of the indicator ring on the hardness bar against a graduated scale. Conversion tables, giving the equivalent Rockwell C, Rockwell B, Brinell, and Shore hardness-scale readings, are supplied with the instrument.

Objects weighing 4 lb or more require no special provision for testing. Smaller objects, however, such as small machine parts, tools, and sheet material, should be placed on a steel block or anvil, as shown in the illustration, to provide sufficient mass. A special anvil for this purpose is available, if required. For testing rolls of from 4 to 16 in., or 16 to 24 in. in diameter, a prismatic stand with water level, as shown, can be provided. The instrument is supplied in the nylon-reinforced rubber case illustrated, 7½ in. in length by 1 in. in diameter, the weight of the instrument and container being only 9 oz.

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ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Rubber Springs for Vehicle Suspension.

By A. E. MOULTON and P. W. TURNER. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, December 11, 1956, 12 pages, 22 illustrations.)

IN automotive design, of the many current problems which beset the designer, suspension is, perhaps, one which has a paramount influence not only on the safety and ease of handling of the vehicle but also a marked psychological and physiological effect on the occupants. The authors believe that rubber is especially suitable as a suspension medium because of its intrinsic properties and also because of the intriguing variety of possible forms into which it can be made, and that it will therefore take its place with coil springs and torsion bars as an accepted vehicle suspension, perhaps eventually supplanting them, as it has already in other fields. Accordingly, the authors have carried out during the past few years, in collaboration with a number of vehicle manufacturers, a research programme of practical tests to confirm the suitability of rubber for suspension purposes, and to realize its potentialities by the development of some modern forms of rubber springs, especially those depending on rubber-to-metal bonding. This latter technique has greatly increased the number of possible forms of spring.

At the outset of the investigation it was apparent that, in comparison with the enormous practical experience on steel springs, there is a lack of information on the fatigue characteristics of rubber springs and especially correlation between laboratory fatigue testing and service life ; consequently, a twin programme of field and laboratory testing was undertaken. Laboratory work included, in addition to the fatigue testing of a wide diversity of spring types, the development of a method of strain measurement for springs of irregular shape and the determination (for the first time, so far as is known) of a basic parameter of fatigue applicable to any type of rubber spring. An analysis of the overall cost of rubber suspension, compared with present-day steel spring practice, was also carried out. Service testing included the investigation of endurance characteristics. Optimum values for the static deflection, damping and low-temperature properties, permanent set, and noise isolation were also studied.

As a result, the authors consider that their tests have demonstrated the practicability of rubber as an automotive suspension medium and as an alternative to steel springs, and that it is able in its several forms to offer, depending on the particular form chosen, a simplification of the design by providing wheel location, a measure of inherent damping (sufficient in certain vehicles to eliminate the need for additional dampers), and, provided that the design is studied from the beginning to include rubber suspension, competitive cost in volume production. Rising rate characteristics, a degree of noise isolation, and, as long as certain fundamental design parameters are adhered to, satisfactory fatigue life are readily obtained.

Development of Hot-Wire Anemometers for Measuring Axial Components of Velocity.

By J. F. KEMP. (From *Journal of The Institution of Heating and Ventilating Engineers, London*, Vol. 24, December 1956, pp. 375–383, 8 illustrations.)

THE study of human reactions under the extreme climatic conditions encountered in deep-level mining imposes as one of its requirements that the sensible heat loss from a test subject in a uniform air stream be measured by direct methods. The problem can be solved by determining the gain in sensible heat of the air stream as it flows past the test subject. This involves measurements of the temperature and velocity distributions in the wake of the person and in a reference plane situated at right angles to the undisturbed upstream velocity.

The anemometers to be used for determining the velocity distribution should be set up with their axes normal to the reference plane, and a basic requirement is that this type of instrument should be capable of measuring only the components of velocity along its axis, i.e., normal to the plane. The nature of the investigation demands that individual tests be performed expeditiously. Instead of traversing the wake with a single instrument, several anemometers, suitably positioned at various points in the reference plane, should therefore be operated to obtain simultaneous readings over a short period of time. If at all possible, the indication of axial velocities should be in terms of an electrical unit, such as an e.m.f., which can readily be recorded for each individual anemometer during test runs.

Having considered various types of anemometer, it was decided to concentrate all efforts on the development of a hot-wire instrument, this type conforming to most of the secondary requirements. Two hot-wire anemometers, having casings of distinctly different shape, were developed for measuring axial components of velocity in a three-dimensional, unsteady field of flow. Originally, an instrument was required to operate at velocities between 0·5 fps and 20 fps, but Reynolds-number effects on the directional response characteristics in this range appeared to be so important that it was found necessary to adopt two shapes of casing in order to obtain good accuracy of measurement. One of the two instruments is suitable for speed measurement between 10 and 20 fps and is capable of measuring the axial components of velocity over a range of incidence of approximately — 60 to + 60 deg. The second instrument was developed for use below 10 fps, and its accuracy over the same range of incidence is reasonable down to 2 fps. Below this value, scale effects become very marked. By increasing the size of the anemometer the effective range of operation can be extended to approximately 1 fps, but below this velocity other limiting factors enter into the problem. A simple circuit diagram is described which enables a single operator to control any required number of instruments simultaneously.

A Laboratory Method for Evaluating Corrosion Inhibitors.

By G. A. MARSH and E. SCHASCHI. (From *Corrosion, U.S.A.*, Vol. 12, No. 11, November 1956, pp.18–22, 9 illustrations.)

CORROSION systems in which two or more phases are present are common in the petroleum industry in diverse forms. In recent years, product-soluble inhibitors (" gasoline rust inhibitors ") have been developed for corrosion protection of pipe lines and tankers. Laboratory evaluation of these inhibitors has usually been effected by means of some modification of an ASTM turbine-oil rust test, which, while well suited to its original purpose, has been found by a number of laboratories to be unsatisfactory for evaluating gasoline rust inhibitors.

The principal objections to the modified ASTM test are that it is qualitative and that it is somewhat subjective. Other objections are that the test is sometimes not reproducible, and that it is rather mild. The test

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			PSI	°F	
Littlebrook 'C'	7	360	975	915	1952-6
Stourport 'B'	1	515	1550	1060	1954
Drakelow 'A'	4	515	1550	1060	1954-5
Connah's Quay	6	300	625	825	1954-7
Portobello	2	540	1400	965	1954-5
Ince	4	550	950	925	1954-7
Skelton Grange 'A'	3	550	975	940	1954-6
South Denes	2	550	950	925	1956
Willington 'A'	3	830	1600	1060	1956-8
Drakelow 'B'	1	860	1600	1010/1005	1957
Agecroft 'B'	2	860	1600	1010/1005	1958
High Marnham	3	1400	2450	1060/1005	1959-60

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also may not distinguish between inhibitors and detergent materials which prevent rust from adhering to the metal specimen. However, the qualitative aspect alone makes the test unattractive.

A more severe test which was considered for gasoline rust-inhibitor evaluation was the Navy static water-drop test. Like the ASTM turbine-oil rust test, the Navy test can be modified in several ways ; here again, however, the results are a matter of inspection and comparison of rust spots ; quantitative results are lacking.

Several workers have recently applied a conductance method to this problem, and satisfactory results have been reported, provided that the temperature is held constant to within 0·1°F. The conductance method has the advantage that the metal cross-section (and therefore loss in thickness resulting from corrosion) can be followed without the necessity for interrupting the test.

The test described in this paper is based on the conductance method, but close temperature control is unnecessary, because of the design of the corrosion-sensing element or probe used. The test appears to be more severe than the modified ASTM turbine-oil rust test ; this is desirable when studying tanker corrosion inhibitors. The method also is adaptable to testing inhibitors for other multiphase corrosion systems, including some where higher temperatures and pressures are involved.

Unlike weight-loss methods, this new screening method is well adapted to following non-linear corrosion-time curves, such as those commonly found when adsorption-type inhibitors are used. The method makes use of quart bottles containing the corrosive agents ; the bottles are rotated end over end at about 3 rpm. This rotation brings about alternate immersion of test probes, where the corrosive system consists of two or more phases. The test probes are used to follow the course of corrosion without requiring the bottles to be opened. A probe consists of a corroding specimen (metal ribbon), to which is attached a protected specimen serving as a temperature-compensating element. These specimens form two arms of a resistance-measuring bridge. Electrical leads, brought through a rubber stopper to the outside of the bottle, permit the probe to be connected, when desired, to a bridge circuit which internally converts any change in resistance to loss of metal thickness. The corrosion loss in millionths of an inch is read directly from a meter and can be followed conveniently during the course of the test. An application of the method in testing gasoline rust inhibitors is discussed, and a comparative study of two gasoline rust inhibitors illustrates the type of information yielded by this method.

An Experimental Investigation of the Process of Expanding Boiler Tubes.

By J. M. ALEXANDER and H. FORD. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, January 4, 1957, 19 pages, 24 illustrations.)

PREVIOUS investigations into the expanding of joints have gone some way to establishing some of the more important factors affecting the tightness and strength of such joints, but further elucidation of the relative importance of these factors is needed. This is particularly so for boilers operating at high pressures and temperatures, where the deformations can be expected to be larger and the stressing of the joints more severe. Most of these investigations, however, have related to the quality of the joint when expanded, whereas the way in which the stresses and pressures build up during the actual expanding process, and the corresponding deformations in the tube and plate, have not been examined. These quantities must depend on the type and dimensions of the expanding tools, but much more experimental work is needed before reliable conclusions can be drawn.

In undertaking a new investigation of the tube expanding process, therefore, the proper starting point seemed to be to trace the actual development of the joint. The object would be to relate the behaviour so recorded with the effectiveness of the resulting joint. The objectives of the work described in this paper were to examine the tube expanding process in relation to as many variables as possible and to determine whether there would be any significant " size effect ". While this general investigation is not yet complete, the results already obtained justify their submission at this stage.

For these investigations an apparatus has been constructed which enables detailed observations to be made of the behaviour of a specimen-tube-plate joint during expanding. A typical record is given showing how the strains and mandrel torque develop during expanding. No appreciable size effect was found on the three geometrically similar systems tested. It is shown that the residual strains are much greater on the back than on the front of the plate, leading to lack of parallelism in the joint face, and that the plastic-elastic interface can extend much further into the plate than was previously thought possible.

Comparison is made between these experimental results and the predictions of a theory proposed by the authors, and it is concluded that higher seat pressures could be obtained if axial extrusion of the tube could be restricted. This finding was confirmed by axially compressing short lengths of tube into a plate, the axial compression causing the tubes to bulge and expand themselves into the plate seat.

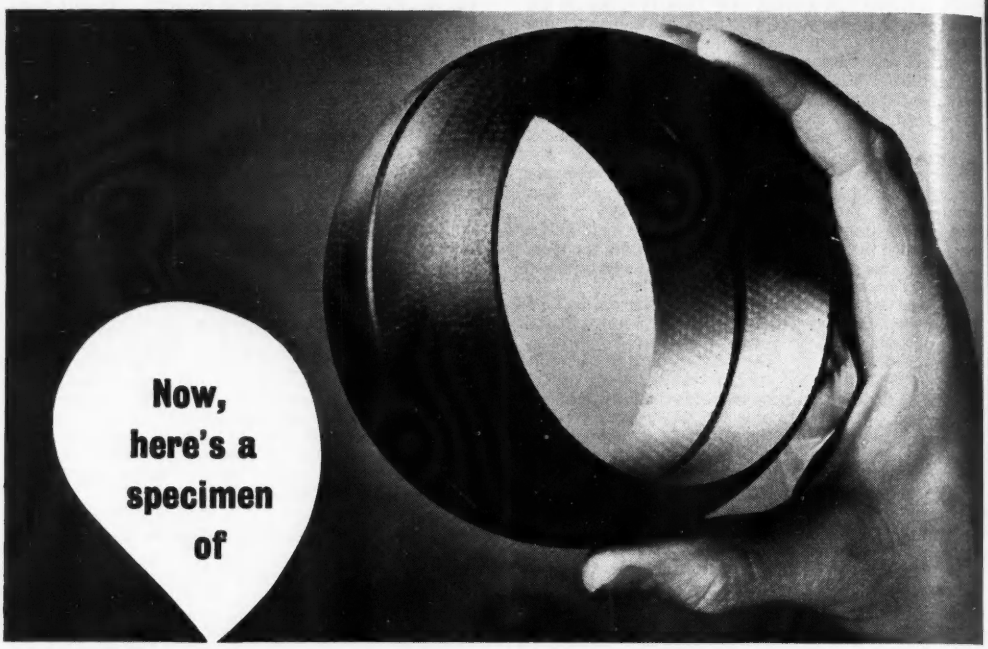
Comparative Studies of Methane and Propane as Engine Fuels.

By N. P. W. MOORE. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, December 1956, 12 pages, 12 illustrations.)

THE performance of methane and propane in an internal combustion engine is of interest for at least two reasons, i.e., because these gaseous fuels are available as natural or waste products in abundant qualities and because they are available in a relatively high state of purity. These fuels have been extensively studied in laboratory experiments, from which the basic processes of combustion have been described, so that it is possible to compare engine and non-engine experiments in some detail. The comparison between methane and propane is also of some theoretical interest, since these two fuels, close together in the paraffinic series, are known to have quite different ignition characteristics in a static-bomb experiment.

The performance of a single-cylinder, high-speed, spark-ignition engine has been studied with gaseous methane and propane as fuels and is described in this paper. The power output and thermal efficiencies have been determined at two compression ratios (5·5:1 and 10:1), and a comparison for the same engine using liquid fuels is given. Both fuels will knock at high compression ratios ; the limits have been determined for all ignitable mixture ratios, and also the effect of inlet temperatures has been studied. Both fuels are " temperature-sensitive ", the effect being most marked with methane. An experimental comparison has been made of the auto-ignition limits of both fuels by the motored-engine method. Both fuels have been shown to give a stable region of visible cool-flame type of pre-reaction below the temperature for complete ignition.

Despite the differing ignition temperature and pressure relationship determined by static experiments, a close similarity is revealed by auto-ignition experiments in the engine. Possible explanations of the differing effects are considered. Infra-red absorption gas analysis has been used to detect the small quantities of methane in the exhaust gas surviving combustion. A very low and constant concentration of methane is present with fast-burning mixtures, owing, it is believed, to valve overlap and scavenge effects. As the rich and weak mixture limits for steady running are approached, unburnt methane increases in the exhaust, the effect being most



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marked near the weak limit. These effects are relevant to problems of atmospheric pollution from engine exhausts, and also assist in assigning the fall in engine efficiency at weak mixtures primarily to combustion inefficiency.

Both methane and propane are shown to be suitable fuels for high-compression-ratio gas engines. Consideration of the combustion properties of these two pure hydrocarbons of simple structure is also of interest in extending the understanding of the general problem of engine knock.

Small Oil-Free Bearings for Aircraft Clocks and Similar Instruments.

By H. S. WHITE. (From *Journal of Research of the National Bureau of Standards, U.S.A.*, Vol. 57, No. 4, October 1956, pp. 185–203, 12 illustrations.)

IT is essential that aircraft instruments and devices operate satisfactorily over a wide temperature range. At sub-zero temperatures, increased viscosity and congealing of lubricating oils result in high friction with lubricated bearings. The non-spreading watch and clock oils conventionally used for lubricating jewel (sapphire) bearings are not satisfactory at — 50°C, and at ordinary temperatures the necessity for periodic cleaning and oiling during shelf storage and during service is, of course, not desirable.

Because of the unsatisfactory performance of lubricated aircraft clocks at low temperatures, a project was initiated to investigate materials which may be suitable for use as oil-free bearings in timepieces, between — 55° and + 70°C, to replace jewels requiring lubrication. Bearing materials included in the investigation were plastics, plastics with fillers, impregnated metals, and impregnated carbon. Corrosion-resistant shaft materials were also investigated. The work consisted of determining the friction and the wear characteristics of the materials, and trial of the more promising materials in timepieces.

Friction tests were made with an inclined-plane type of static-friction apparatus, and with shafts rotating in loaded journal bearings, at temperatures from — 55° to + 70°C. With bearings of typical materials stored on steel shafts, the effect of shelf storage on static friction was investigated. Wear tests were made with loaded bearings on ¼-in. diameter rotating shafts made of different types of steel. With oscillating ⅛-in. diameter shafts and 1000-gm loads, wear data were obtained on bearings of the more promising materials. Using an endstone wear-testing machine, wear data were obtained for end-thrust bearings made of typical bearing materials, and the performance of oil-free bearings in eighteen timepieces was investigated.

No material was found to be as satisfactory as diamond for use as a thrust-bearing material under conditions of high load such as that occurring at the balance-shaft upper endstone in chronometers. Similarly, no material was found to be as satisfactory as sapphire for use as pallet stones in timepieces. Sapphire appeared to be suitable for use as unlubricated endstones when the load was relatively light, especially in timepieces normally operating in an upright position. Unlubricated (clean) sapphire hole bearings (jewels) caused rapid wear or rusting of the conventional balance-staff pivots in timepieces. Boron carbide without lubrication did not appear to be suitable for use as pallet stones or as a journal-bearing material. Under the conditions tested, ordinary brass and bearing bronze conventionally used for making small bushings did not appear suitable for this application without lubrication.

In journal bearings, a fused coating of polytrifluorochloroethylene (PTFCE) plus graphite gave good resistance to wear, but the friction was relatively high. A fused coating of polytetrafluoroethylene (PTFE) one-coat enamel gave lower friction, but the resistance to wear was somewhat less than with the above coating. Both of these coatings wore rapidly when tested as thrust bearings. Because of the thickness of the coatings ordinarily used and the difficulty in making a uniform coating with a good bond on small parts, the use of coatings of this type does not seem practical for journals or bearings less than $\frac{1}{16}$ in. in diameter.

Silver amalgam gave exceptionally low friction at room temperature. However, this material was very brittle, and the edges of the hole chipped badly during boring and reaming operations. An amalgam of dental-alloy filings was also tried ; this was less brittle than the silver amalgam, but the bearing gave increasingly high friction at the start of a test, and scuffing of the bearing soon occurred.

The Life and Reliability of Electronic Valves.

By K. RODENHUIS, H. SANTING, and H. J. M. VAN TOL. (From *Philips Technical Review, Holland*, Vol. 18, No. 7, 1956–7, pp. 181–192, 11 illustrations.)

OWING to the serious consequences that may arise from the failure of a valve in professional equipment, the conventional requirements, e.g., with regard to the mutual conductance, power dissipation, suitability for wide-band amplification, etc., are no longer adequate. It is evident that valves used for professional equipment should satisfy the additional requirement of reliability, as the equipment should be ready for operation at all times and there must be no risk of sudden failures. Other properties which may be important are long life, shock resistance, and narrow tolerances in electrical characteristics, although they may not all be equally necessary in every application. For instance, long life and constant electrical characteristics are required for valves used in computers and in telephone repeater amplifiers, but ruggedness is not so necessary, since in this equipment the valves are not subjected to mechanical vibrations or shocks. On the other hand, the valves used in aircraft transmitters and receivers must be able to withstand severe vibrations and shock, though some variation in characteristics is usually to be tolerated, and service life presents no problems where the equipment is in operation only for short periods per day.

In recent years there has been a substantial increase in the use of electronic equipment. Not only have telecommunications developed enormously, but new fields of application have been opened up. Typical examples are industrial measurement and control equipment, electronic computers, and many new kinds of navigational aids for ships and aircraft. A modern airliner, with radar, may have as many as 500 valves in its equipment. Moreover, the military use of electronic equipment has expanded on a vast scale. Thus, there may be as many as 2000 electronic valves in a large bomber and 10,000 on board a battleship. As a result of the rapidly increasing use of electronic valves in industrial equipment, aircraft, etc., far more attention is being paid to the reliability of these components than ever before, particularly in view of the often serious consequences of a valve failure in complex equipment.

In this article, new definitions are given for the related concepts " reliability " and " life ". The authors define " reliability " as the reciprocal of the failure rate, i.e., the percentage failures in a batch of valves after 1000 hr of operation. They regard the end of the useful life of a valve as the moment at which the failure rate begins to increase. A useful life of 10,000 hr and a failure rate of 0·5% per 1000 hr have already been reached with " special-quality " type valves, and it is hoped to be able to reduce the failure rate to 0·1% per 1000 hr. Valve failures may be either gradual or sudden. The causes of both categories of failure are discussed separately and a description is given of the measures taken in recent years to reduce the incidence of valve defects. The spread of characteristics and shock and vibration resistance are also discussed. In addition, the desirability of close co-operation between valve manufacturer and valve user is underlined.

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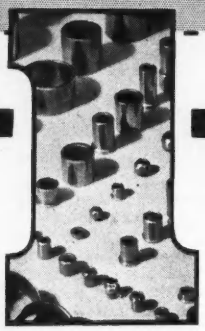

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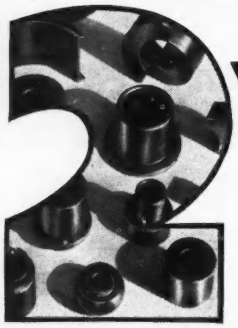

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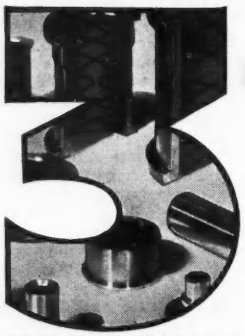

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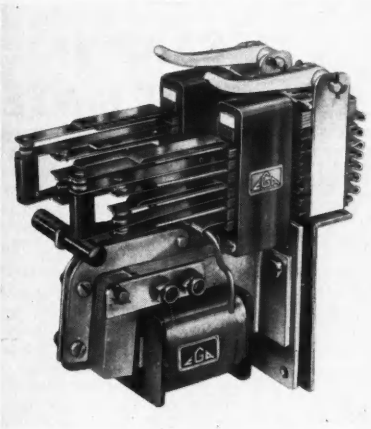


Fig. 1.

As shown in Fig. 1, the unit consists of a relay and terminal base, which can be mounted and wired into position before the relay proper is plugged in, there being no soldered connections to the relay itself. Fig. 2 shows the same relay withdrawn from the terminal base, with the cam levers in the "up" position and the contact jaws in the base in the "open" position. The plug-in contacts are compressed in series and locked into position, so that there is no likelihood of a faulty or light connection from vibration or other causes, and the magnet-coil supply leads are connected to the bottom plate of the finger boxes. In this form, the relay occupies little panel space and makes for neater and quicker wiring; at the same time, any possibility of damage to the relay contacts during the wiring process is eliminated.

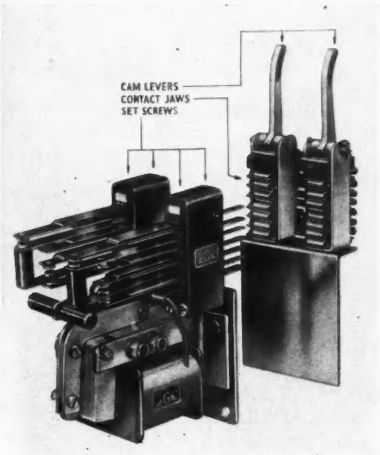


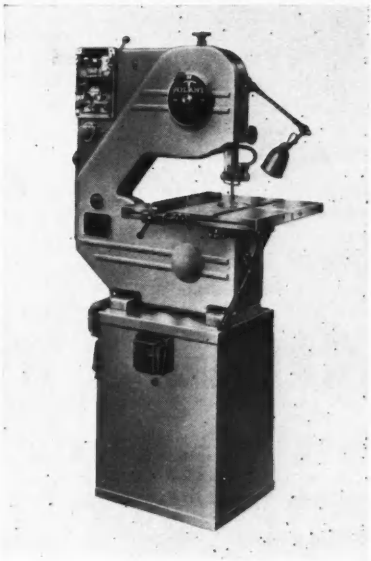
Fig. 2.

The fingers and insulation pieces are assembled in a moulded box-frame and are compressed by set-screws against a squash-plate, as distinct from the usual method in which fingers and insulation pieces are all pierced to provide screw holes. As a result, perfect insulation and excellent contact pressure are obtained, and it is a simple matter to replace a bent or faulty finger merely by loosening the set-screws at the top of the box. The entire finger-box is fixed to the base by two screws, accessible from the front, and each finger box can accommodate up to seven fingers. Of these, one finger is used for the magnet-coil supply, the remaining six fingers being used as three pairs of normally open contacts, three pairs of normally closed contacts, or two sets of single-pole change-over contacts. However, variations, up to a maximum of six fingers per box, are possible.

The complete magnet assembly can be dismantled by loosening two screws. The coil can then be removed, once the main bearing pin is withdrawn and the coil retaining washer loosened. The coil former is constructed of green bakelite, the coil being vacuum-impregnated. The coils can be wound for all voltages from 4 to 440 V a.c., and from 6 to 230 V d.c.

MULTI-PURPOSE BAND MACHINE

A recent addition to the range of light machine tools manufactured by the Startrite Engineering Co. Ltd., of Gillingham, Kent, is their "Volant" 10-speed multi-purpose band machine, which has been designed to broaden the usefulness and to extend the advantages of continuous band machining. With a throat capacity of 18 in., a depth under guides of $5\frac{3}{4}$ in., and a speed range between 56 and 3200 fpm, the new machine is capable of machining to shape a wide range of industrial materials, including wood, plastics, aluminium, brass, cast iron, mild steel, and tool steel. It is available with a built-in welder, a blade cropper, a grinding unit, a job-selector



Whether you want to convey

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– keep down your costs by using 'job-designed' Goodyear belts

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QUICK DELIVERY

You can now get quick delivery of Goodyear conveyor belts, which are available with cotton or rayon plies. They can be supplied in a few weeks against specific ordering.

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INDUSTRIAL RUBBER PRODUCTS

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dial, an air jet, and a low-voltage spotlight, and is suitable for repetitive operations involving sawing, slicing, parting, and slotting, as well as the inside or outside cutting of cams, punches, dies, etc.

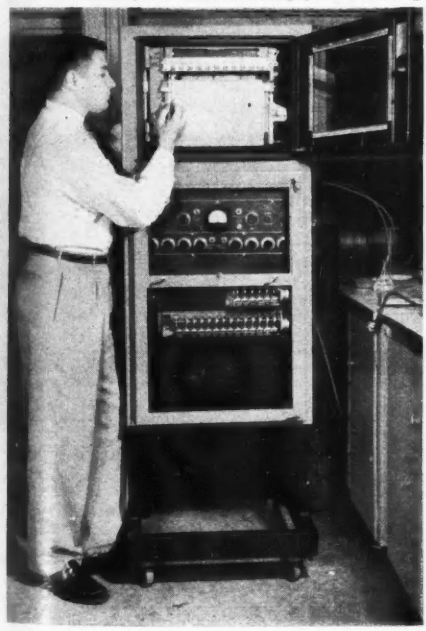
The machine, which operates with a band tool 95 in. in length and from $\frac{1}{8}$ to $\frac{1}{2}$ in. in width, has a single-piece cast frame member, with a large hinged door, providing ample clearance when changing tools. The steel disc band-rolls are rapidly interchangeable for tyre service, and the upper wheel includes blade-tensioning and tracking gear. The cast-iron work-table, 20 × 19 in., swivels 45 deg. right and 5 deg. left on a dual trunnion casting. A tee-slot is machined in the table-apron face to carry a fence attachment with a fine screw control. Guide-pieces are adjustable throughout by similar controls.

The built-in welding apparatus is automatic in operation and includes a motorized weld grinder, a blade-squaring shear, and an annealing switch. The unit is conveniently located for making up band tools from "coil" stocks, or for rejoining a band after it has been run through a starting hole. The low-voltage spotlight and air jet, which is operated from a small air-pump, are suitably located at the work-station. The job-selector dial gives the operator all factors for most efficient machining, showing the type and speed of tool to be used for the composition and thickness of material to be machined.

CONTINUOUS GAS CHROMATOGRAPH

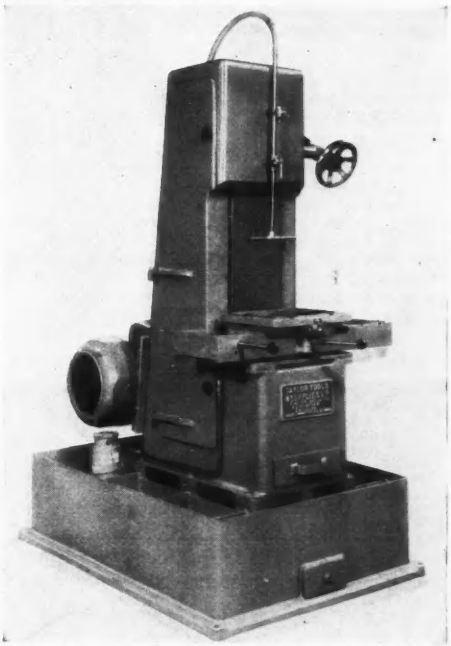
Fulfilling the need for a simple and reliable method of analysing industrial gas streams, a new continuous gas chromatograph has been developed by Beckman Instruments, Inc., of Fullerton, California. In this connection, the analytical instruments commonly available have been found to be satisfactory in the laboratory, but lack the sturdiness and dependability needed for plant or refinery use; as a result, it has usually been found necessary to control such processes by monitoring secondary effects such as temperature, pressure, and flow.

On the other hand, the new Beckman Process Gas Chromatograph is a compact and rugged device designed to make continuous samplings of any gaseous process stream. Each sample is automatically passed through a packed column of absorbent material, which breaks the mixture into its component parts and then registers on a graph the percentage of each chemical component present. This information can be fed into a relatively simple control system for keeping track of the reaction and for automatically correcting any deviations.



WET BELT GRINDER

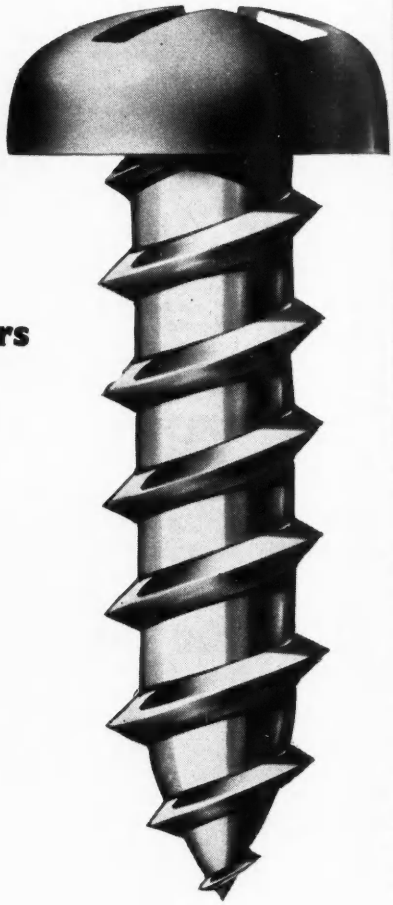
A new 9-in. wet belt grinder, designed to derive the highest possible efficiency from the latest electro-coated, resin-bonded abrasive belts, is announced by Taylor Tools & Supplies Ltd., of Broadheath, Altrincham. An outstanding feature of this design is that the abrasive-belt pulleys, both driving and idler, are not overhung, but are supported on both sides in large ball and roller bearings, housed and protected by labyrinth seals. Conveniently located handwheels provide for tensioning and tracking of the abrasive belt, which has a length of 108 in. and which operates at between 2500 and 5500 fpm, according to requirements.



The base of the machine forms a large-capacity settling tank, with multiple compartments for clearing the coolant before it is recirculated by the pump. A readily removable drawer collects heavy swarf before it can reach the tank. A motor-driven centrifugal pump is housed in one compartment of the tank and directs coolant to three points, i.e., above the work for cooling purposes; at the back of the abrasive belt, to lubricate it in its passage over the platen; and below the work-table, cleaning swarf from the surface of the belt, so that the abrasive can operate efficiently when it again contacts the work. A hinged door on the side of the main column gives quick access to the abrasive belt, which can be changed in under one minute. The motor is mounted on a hinged base-plate, so that the tension of the V-belts can be readily adjusted. The illustration shows a hand-operated micrometer table with anti-friction ways. This table is tee-slotted and can be traversed clear of the belt for work setting. The micrometer stop permits repetition sizing. Automatic work fixtures or a plain fixed table can, however, be supplied in place of the table shown.

the more you think of it

the better it appears



So, then, let us think of it ; the self tapping screw, applied to your products. What does it offer you?
Well, first, by forming its own thread, it cuts out every standard tapping operation along the line. It obviates the use of nuts.
And, with its self-locating point, it makes assembly an easier job.
Whether you produce in steel, wood, plastic or non-ferrous metal, the self tapping screw provides the cheapest, quickest and strongest method of fixing.
The more you think of it — well, the more you think of it.

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Beardmore

NEWS OF THE MONTH

PERSONAL

Mr. W. C. Morgan, Commercial Manager of E.M.I. Electronics Ltd., has been appointed Engineering Director of the company. He will remain in charge of Contract Sales and for the present will continue, jointly with the Managing Director, to be responsible for the company's general sales activities.

Midland Heating & Ventilation Co. Ltd., Birmingham 11, makers of Midac Dust and Fume Control Plant and Aquamiser Cooling Towers announce that **Mr. K. S. Smith** has been appointed as their Northern Representative and that he will operate from 44 George Lane, Bredbury, Stockport. Telephone: Woodley 3611.

At a recent meeting of the Council of the Gauge and Tool Makers' Association, the following officers were appointed for the new Session 1956–7 : **Mr. F. W. Halliwell, C.B.E., M.I.Mech.E., M.I.Prod.E.,** Chairman and Joint Managing Director of Gay's (Hampton) Ltd., has been re-elected President of the Association. **Mr. S. J. Harley, B.Sc., M.I.Mech.E., M.I.Prod.E.,** Chairman and Managing Director of Coventry Gauge & Tool Co. Ltd., has been re-elected Deputy-President of the Association. **Mr. A. L. Dennison, M.I.Prod.E.,** Chairman of Birmingham Tool & Gauge Co. Ltd., and **Mr. H. S. Holden, M.I.Prod.E.,** Managing Director of Brooke Tool Manufacturing Co. Ltd., have been re-elected Vice-Presidents of the Association. **Mr. T. Ratcliffe, M.I.Prod.E.,** Chairman and Managing Director of Ratcliffe Tool Co. Ltd., previously a Vice-Chairman of the Association, has been elected a Vice-President of the Association. **Mr. L. E. Van Moppes,** Director of L. M. Van Moppes & Sons (Diamond Tools) Ltd., has been re-elected Chairman of the Association. **Mr. G. P. Barrott, M.I.Prod.E.,** Director and Secretary of Precision Grinding Ltd., has been re-elected a Vice-Chairman of the Association. **Mr. R. Kirchner, M.I.Mech.E., M.I.Prod.E.,** Joint Managing Director of Arnott & Harrison Ltd., previously Honorary Treasurer of the Association, has been elected a Vice-Chairman of the Association. **Mr. H. G. Carmichael Wilson,** Managing Director of John Harris Tools Ltd., has been elected Honorary Treasurer of the Association. In a recent ballot amongst the 336 firms in the Association to fill certain vacancies on the Council for the new session, the following were elected as new Members of Council : **Mr. S. E. Coley,** Managing Director, Coley Bros. (Tools) Ltd ; **Mr. H. S. Hallewell,** Managing Director, Toolmasters Ltd. ; **Mr. A. M. C. Murphy, A.Met., F.I.M.,** Works Director, Hall & Pickles Ltd. ; **Major-General E. P. Readman, C.B.E., T.D.,** Managing Director, English Steel Tool Corporation Ltd.

Contactor Switchgear Limited, Moorfield Road, Wolverhampton, announce that **Mr. G. C. Handley** has relinquished his appointment of London Manager in order to return to the North of England. **Mr. G. E. Jones** has been appointed in his place.

Mr. M. Lyth, M.A., A.M.I.Mech.E., has been appointed Production Manager of the Lincoln Electric Co. Ltd., Welwyn Garden City, Herts. Mr. Lyth was formerly a management consultant with Production Engineering Ltd.

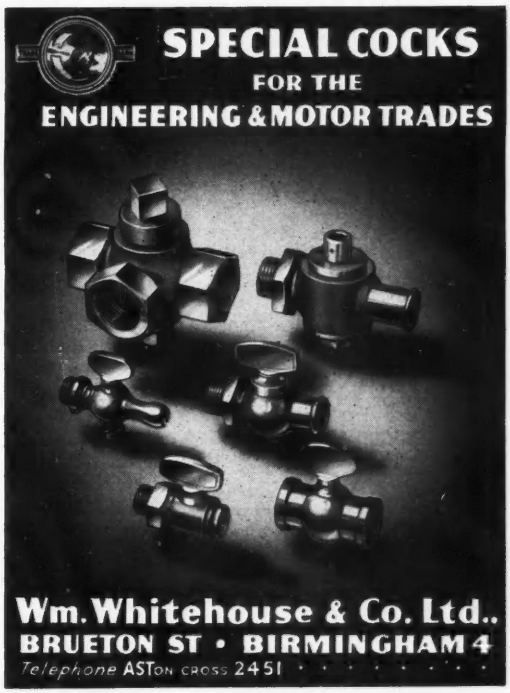
Plowright Brothers Limited, Chesterfield, announce that **Mr. D. F. Wagstaff, A.M.I.Mech.E.,** has been appointed Chief Engineer and **Mr. G. L. Doris, B.Sc., A.M.I.Min.E.,** appointed the Technical Sales Manager.

The Council of the O.E.E.C. has appointed **Dr. Alexander King, O.B.E.,** Deputy Director of the European Productivity Agency. On 1st January, 1957, he succeeded Mr. Edwin Fletcher, who has returned to the T.U.C. from which he was seconded in 1955. As Chief Scientific Officer in the Department of Scientific and Industrial Research (D.S.I.R.), which he joined in 1950, Dr. King has been responsible for work on productivity (including research on industrial operations, human relations and industrial economics), technical information services and overseas scientific relations.

Mr. John Spiers (A.M.I.Mech.E.) has been appointed senior experimental engineer in the Experimental Department of F. Perkins Ltd., the Peterborough diesel engine company.

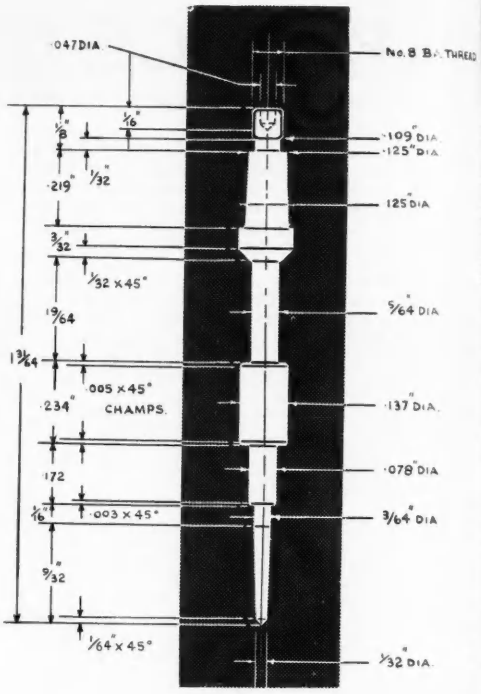
Sheepbridge Engineering Limited announce that **Mr. C. Hand** has been appointed to the board of their subsidiary company, Sheepbridge Equipment Limited.

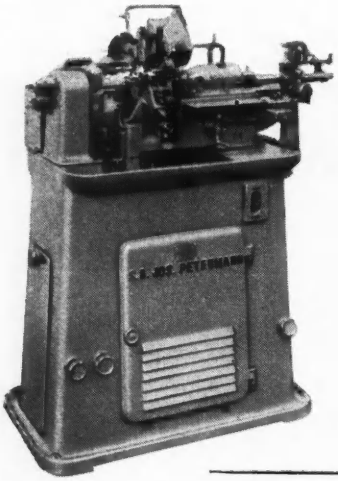
Metropolitan-Vickers Electrical Co. Ltd. announces that as from 1st September, 1956, **G. H. Butterworth, B.Sc., A.C.G.I., A.M.I.Mech.E., A.M.I.E.E.,** was appointed Superintendent, Mechanical Department, in succession to **Mr. A. C. Anniss** who relinquished this position ; also **A. E. Clayton** was appointed Works Manager and **A. Cormack, B.Sc.(Eng.),** Assistant Superintendent, both at Germiston Works. As from 1st November, 1956, **Mr. W. O. P. Jones, B.Sc.(Eng.), A.M.I.E.E.,** has been appointed Assistant Superintendent, Electronics Department.



22 seconds

This component of mild steel is produced on a Petermann P.4 (4 mm.) machine in 22 seconds, and is but one example of the many components which Petermann Automatic Precision Lathes are ideal.





- Adjustable speeds 3,050-12,200 r.p.m.
- Capacity up to 5/32in. dia. by 1·57in. long.
- Six tools in independent holders.
- Headstock controlled by cams and adjustable followers.
- Screw head slotting attachment can be used.
- Other Petermann models available.

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BUSINESS NOTES

Analogue Computers designed and built by **Short Bros. & Harland Ltd., Belfast,** are to be demonstrated to leading German and Swedish engineers and mathematicians in Brunswick and Stockholm this month. In these demonstrations the machines will solve abstruse problems submitted as representative of those encountered in research and development now in hand in the respective countries. In Germany, the Short Computer is to be demonstrated at Brunswick Technical College from 10th to 31st January, when the Colloquium of Technical Colleges of Lower Saxony is to be held. Among those present will be prepresentatives of Berlin Technical University, Gottingen University and Hanover Technical College. The computer to be shown in Sweden will be shipped to Stockholm at the end of January. Organizers of the demonstration are the Stockholm firm, Stenhardt Ingeniorsfirma AB, who have invited Swedish universities and colleges to submit special problems. The firm will also demonstrate the computer to the Swedish Government and a number of industrial establishments.

Over 2000 visitors attended the recent exhibition held by **E.M.I. Electronics Ltd.,** at the Royal Hotel, Woburn Place, London, from the 28th to 30th November.

An impressive display totalling more than 100 items of industrial and laboratory equipment showed how widespread the activities of this company have become. Perhaps best known in the past for their Cathode Ray Oscilloscopes, Dynamic Balancing Machines and Magnetic Tape Recorders, their production now includes microwave equipment, selective and wide-band amplifiers, industrial television equipment, stroboscopes, tachometers and vibration generators. Although not shown at the exhibition E.M.I. are producing a completely self-contained system of electronic machine tool control which is claimed to be lower in cost than other systems which are dependant on an external computer service. Business machines and automatic process control are two other important activities which had to be omitted from the display.

Instruments of special interest include the new Hand Stroboscope type 5 which operates on 220/240V 50c/s mains and provides a range of 300 to 6000 rpm. In the same field the Multistrobe type 1 enables either a large area to be illuminated or several small areas at one time. Up to four lamps of 30W maximum power can be synchronously driven from the internal oscillator with provision for triggering from an external source or a photo-electric transducer. The facilities for environmental testing using British equipment are now greatly increased with the availability of the Type EMV5 Vibration Generator which will provide a 3000lb thrust through a maximum excursion of 0·9 inch over a frequency range of 1c/s to 25c/s and 300c/s to 950c/s. Good design of the audio power drive amplifier has reduced the necessary consumption to only 5kW. A smaller generator giving a thrust of 120lb over a frequency range of 20c/s to 7kc/s is also available. Throughout industry there is often the need for an inexpensive portable Oscilloscope and the E.M.I. Type 2300 has a specification to cover the majority of requirements. Weighing 61b it has a 2½ inch screen and provides a level frequency response from d.c. upwards to 100kc/s.

The Diamond Screw & Cotter Co. Ltd., Cherrywood Road, Bordesley Green, Birmingham 9 celebrates its Jubilee Year in 1957 having been established in 1907. The firm is fully approved by M.O.S. 6/49 and Air Registration Board, and supplementing its Birmingham and Midland Organization it has London and Glasgow offices and representatives in the Eastern Counties, Manchester and South Wales.

British Insulated Callender's Cables Ltd., announce that their depot at Camden Street, Derby, now has an additional telephone number—Derby 44282.

The Electrical and Electronics Section of the **Scientific Instrument Manufacturers' Association** (SIMA) recently celebrated the tenth anniversary of the formation of the section. It was founded on 12th December, 1946 and comprised fifteen member firms; today there are fifty-three primary members of the section and thirty other members have a secondary interest in the Section's activities, making a total of eighty-three out of the whole SIMA membership of 150 instrument firms. At a recent meeting Mr. L. A. Woodhead, who is director and general manager of Cossor Instruments Ltd., was elected chairman of the Electrical and Electronics Section and Mr. A. E. Evans, managing director of Evans Electroselenium Ltd., was elected vice-chairman.

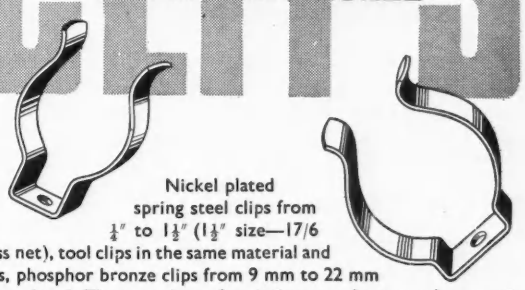
Millett, Levens (Engravers) Limited, Sterling Corner, Barnet By-Pass, Boreham Wood, Herts, announce that they are now able to offer self adhesive nameplates, dials, scales, etc., to the engineering and electronic industries. Chemically engraved brass, anodized printed and embossed aluminium, steel or plastic plates, can all be supplied self adhesive. The plates are immersed for a few seconds in water, the surface film slides off, and by firm thumb pressure, the plates then hold permanently on to almost every kind of surface.

At a joint meeting of **The Institution of Naval Architects and The Institute of Marine Engineers** a Symposium on The Education and Training of Naval Architects and Marine Engineers will be held on 6th February, 1957, commencing at 10.00 a.m. in the Weir Lecture Hall, The Institution of Naval Architects, 10 Upper Belgrave Street, London, S.W.1.

The Copper Development Association, whose headquarters have been at Kendals Hall, Radlett, Herts, since the end of the war, has returned to London, to spacious new premises at 55 South Audley Street, W.1. Telephone GROsvenor 8811.

CLIPS

SPRING STEEL
PHOSPHOR BRONZE



Nickel plated spring steel clips from ⅛" to 1½" (1½" size—17/6 gross net), tool clips in the same material and sizes, phosphor bronze clips from 9 mm to 22 mm —say when ! There are lots of variations on the same theme and if it isn't in stock we can soon make it. Better get in touch with Lewis of Redditch today.

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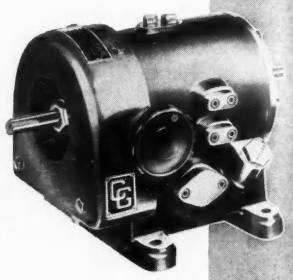
Carter Gears are available in sizes ranging from 0·25 H.P. up to 35 H.P. Complete drives comprising Carter Gear, British Standard Squirrel Cage Motor and, where required, Output Reduction Gear can be supplied. Further details may be obtained on request.



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INFINITELY VARIABLE SPEED GEARS

- ★ *Infinitely Variable Speed Range.*
- ★ *Hand, Electrical Remote or Lever Controls.*
- ★ *Controls may be adjusted with drive RUNNING or STATIONARY.*
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NOW THERE ARE EIGHT

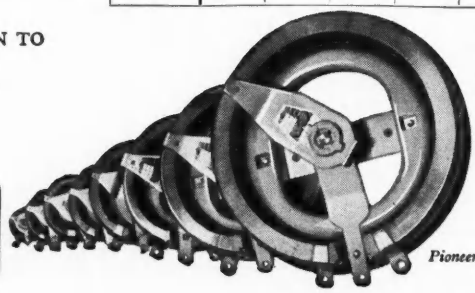
BERCO

TOROIDAL RHEOSTATS

So popular has the original range of five Berco rheostats become that three new models have been introduced. Like all Bercostats they have five important features:—

- * VITREOUS ENAMEL BONDED
- * HIGHEST MECHANICAL STRENGTH
- * MAXIMUM ELECTRICAL PERFORMANCE
- * MINIMUM SIZE IN RELATION TO POWER DISSIPATION
- * CAN BE USED IN TROPICAL SITUATIONS WITHOUT MODIFICATION

Ohms ± 10%	CURRENT RATINGS							
	L.25	L.50	L.75	L.100	L.150	L.225	L.300	L.500
1	—	7.07	8.66	10.00	12.50	15.0	17.3	22.3
2	3.54	5.00	6.12	7.07	8.66	10.6	12.2	15.8
3	2.89	4.08	5.00	5.75	7.07	8.66	10.0	12.9
5	2.24	3.16	3.88	4.77	5.48	6.71	7.75	10.0
7.5	1.82	2.56	3.16	3.65	4.47	5.48	6.32	8.17
10	1.58	2.24	2.74	3.16	3.88	4.74	5.48	7.07
15	1.29	1.83	2.24	2.58	3.16	3.87	4.47	5.78
25	1.00	1.41	1.73	2.00	2.45	3.00	3.46	4.47
50	.707	1.00	1.23	1.41	1.73	2.12	2.45	3.16
75	.578	.818	1.00	1.15	1.41	1.73	2.00	2.58
100	.500	.707	.866	1.00	1.23	1.50	1.73	2.23
150	.408	.575	.707	.818	1.00	1.22	1.41	1.82
200	.354	.500	.612	.707	.866	1.06	1.22	1.58
350	.268	.378	.463	.535	.655	.803	.926	1.19
500	.224	.316	.388	.447	.548	.671	.775	1.00
1,000	.158	.224	.274	.316	.388	.474	.548	0.708
1,500	.129	.183	.224	.258	.316	.387	.447	.578
2,500	.100	.141	.173	.200	.245	.300	.346	.448
5,000	—	.100	.123	.141	.173	.213	.245	.315
7,500	—	.081	.100	.115	.141	.173	.200	.258
10,000	—	—	—	.110	.125	—	.173	.224
15,000	—	—	—	—	—	—	—	.163



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COMMONWEALTH STANDARDS CONFERENCE IN INDIA

Leading members from a number of important British exporting industries will attend the third full-scale Commonwealth Standards Conference to be held since the war in New Delhi, commencing on the 21st January. The main purpose of the conference will be to secure a common approach to, and greater alignment of, industrial standards among member-countries of the Commonwealth, thereby facilitating the flow of trade between these countries. In sessions held to review more general questions of policy, consideration will be given, for example, to the possibility of extending between Commonwealth countries "approval" arrangements such as that which now assists exporters of British electrical goods to Canada, and the effects on Indian standards practice of that country's adoption of the metric system and its consequences for intra-Commonwealth trade.

DUNLOP'S NEW SYNTHETIC RUBBER PLANT

For the first time in the United Kingdom, the experimental production of synthetic rubber on an appreciable scale is about to begin from the Dunlop Rubber Company's new plant at Fort Dunlop, Birmingham. Dunlop's venture is the advance guard of synthetic rubber production in Britain, the latest link in a chain of events begun in Birmingham in 1884 when Sir William Tilden made the first synthetic rubber in his laboratory. The large oil refineries now established at Southampton and elsewhere will shortly be able to provide the necessary supplies of the raw materials butadiene and styrene and make possible the economic production of synthetic rubber of the general purpose type in this country.

Dunlop has been preparing for a long time to be able to take advantage of this opportunity. Research in the fundamental science and technique of synthetic rubbers and development of the manufacture and technology of the products has been going on in the Research Centre for many years, and their scientists have kept abreast of technical and production advances both in Europe and America. As with most chemical processes, progress has been in a series of steps from the laboratory bench to the pilot plant stage or small-scale experimental production. The experience so gained has taught Dunlop how to incorporate all the most modern methods and improved techniques necessary for efficient production and satisfactory quality material In the new plant this work has now reached a small manufacturing scale, and an output of 1,500 tons a year is confidently aimed at. The main objectives of the plant are the production of general purpose rubber for tyres, and of new synthetic rubbers as they are developed by the Central Research Division. It has been designed with both up-to-dateness and flexibility of operation in mind, so that it will be able to produce a wide range of synthetic rubbers that may be developed in the future. The availability of plant facilities of this kind will also enable process and plant modifications to be tried out to gain experience and "know-how" for large scale production.

Ordinary general purpose synthetic rubber is built up from two highly reactive raw materials, the monomers butadiene and styrene. These are first of all emulsified in a dilute soap solution. Special ingredients, such as catalysts, modifiers, etc., are then added, which cause the small globules of liquid to be slowly polymerized into solid particles of rubber. The latex is then curdled or coagulated by adding salt and sulphuric acid and the curds of synthetic rubber are then washed and dried. The monomers butadiene and styrene are stored in the tank farm, isolated a hundred yards from the main building in line with the general regulations for inflammable materials. From here the monomers are brought to the pre-treatment area for treatment by alkali or distillation to remove the added polymerization inhibitors, and are then fed to the reactors. Beyond the reactors is the solution make-up area, where the emulsifiers (soaps) and so on are prepared. The liquids are pumped in metered quantities into the reactors; if cooling is necessary they pass through a heat exchanger on their way to the reactor. The reactors are of steel, glass lined and water-jacketed. Polymerization is carried out at a suitable temperature with constant stirring; a range of controlled temperatures suitable for the production of various types of rubber can be obtained while low temperatures are achieved, if required, by circulating cooled brine. The reaction is stopped when the required conversion has been reached. From the blowdown tanks the unstripped latex is piped for stripping of unreacted monomers. The butadiene is flashed off and the styrene is removed by low pressure steam stripping in patented equipment of Dunlop design. The finished latex passes to storage tanks and from there to the coagulation unit. The coagulated crumb is freed from surplus serum on a vibrating screen, and washed and filtered in a series of operations during which a squeeze-roll conveyor converts it into sheet, which is shredded back to crumb and dried in a three-pass steam heated drier. The dried crumb is fed to a hopper on the weigher which automatically delivers the required weight to the baling press when, and not before, the baler is ready to receive it. The bale of synthetic rubber is dusted in soap-stone, wrapped in a polythene-lined paper bag and stitched up ready for despatch.

The synthetic rubber plant is highly mechanized in that most of the operations once started, run without any further human help. The whole finishing process is mechanical until the wrapper is placed in position by hand. All the safety precautions usually observed in chemical manufacturing plant are applied and the complete plant costing £600,000 is on a 12-acre site, the main building housing the reactors, etc., covering approximately 11,000 sq ft.

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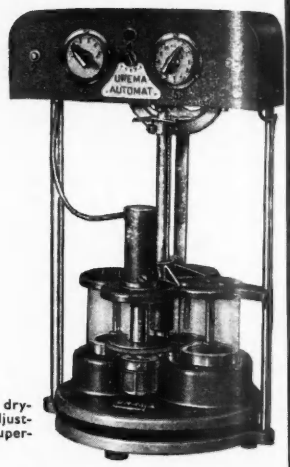

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Marston Excelsior Ltd., a subsidiary of Imperial Chemical Industries Ltd., has taken over from the Billingham Division of I.C.I. the manufacture of bursting discs—safety devices which can be used in any pressure system and which burst if a given pressure is exceeded. The firm is now prepared to meet increased demands for these items of equipment which are of great value in plants operating at pressures typical of modern engineering practice.

Details are now announced concerning the further British Atomic Group which has been formed after consultation with the United Kingdom Atomic Energy Authority and the Central Electricity Authority, to tender for the design and supply of atomic power stations for the United Kingdom and abroad. The companies which have formed this new Group and their respective interests in the design and construction of the Power Stations, are **Richardsons Westgarth & Co. Ltd.,** suppliers of the generating plant including the turbo-alternators, blowers and standby generators; **International Combustion (Holdings) Ltd.,** who will undertake the building of the steam generating equipment, including the reactor, heat exchangers and pressure vessels; and **Crompton Parkinson Ltd.,** manufacturing the switchgear, transformers, cables and motors. Each of these concerns is already established in the construction of plant for conventional power stations. The new organization will be accommodated centrally in an office block recently constructed at 28–30 Theobalds Road, London, W.C.1. The whole of that building has been taken over by the Group. The Group will operate through a Joint Company, **Atomic Power Constructions Ltd.,** with an authorized capital of £1,000,000. The board of Atomic Power Constructions Ltd., consists of:—The Rt. Hon. Lord Coleraine, P.C., as chairman, Mr. Harry Fothergill, a director of Richardsons Westgarth & Co., Ltd., Mr. J. Mayer, joint managing director of International Combustion (Holdings) Ltd. Mr. J. V. Daniel, managing director of Crompton, Parkinson Ltd.

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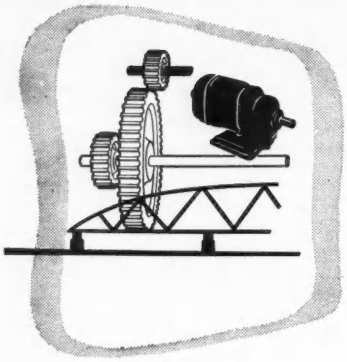

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BOOKS RECEIVED

Electronic Computers. Edited by T. E. Ivall. 175 pages, 93 illustrations. Publishers: Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price: 25/- (postage 9d.).

This non-mathematical introduction to the principles and applications of computers employing valves and other electronic devices is primarily written for technicians, engineers, and students with a knowledge of electricity or electronics, but is also suitable for business executives. The treatment has been made as general as possible, in order to give a broad background picture of the whole field of computing, from which the reader can pass on to more advanced and specialized studies.

Both digital and analogue computers are covered, and comparisons are made between the two types. The bulk of the book is devoted to describing their circuitry and construction, while their rapidly developing applications in industry, commerce, and science are also outlined. Here, considerable emphasis is placed on the application to automation techniques in industry, and also on the use of analogue computers as simulators or models of control systems. In the final chapter the future evolution of computers is discussed.

F.B.I. Register of British Manufacturers, 1957. 29th Edition. 1124 pages. Published by Kelly's Directories Limited, and Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price: 42/-.

This comprehensive and accurate guide to a substantial cross-section of British industry lists the products and services of over 7000 member firms under more than 5400 alphabetical headings. In addition to the Classified Buyers' Guide, there are seven other sections in the Register, giving addresses of companies and firms, and valuable information about trade associations, proprietary names, trademarks, etc. A feature providing a useful reference for buyers not fully conversant with British product terms is the provision of French, German, and Spanish glossaries. These give translations of every product term used in the main buyers' guide, each being numbered for easy reference between the English headings and their translations.

As the only authorized directory of the Federation of British Industries—the largest and most influential association of British manufacturers—the F.B.I. Register is compiled by the publishers in close collaboration with the Federation. As such, it is a valuable source of information to importers, buyers, trade commissioners, chambers of commerce, commercial attachés, reference libraries, departments of trade, and industry, etc., throughout the world.

Cams: Design, Dynamics, and Accuracy. By Harold A. Rothbart. 364 pp., 200 illustrations. Publishers: John Wiley & Sons, Inc., and Chapman & Hall, Limited, 37 Essex Street, London, W.C.2. Price: 76/-.

This useful book is written primarily for the designer concerned with the creation of a mathematical function, motion, mechanism, machine, or mechanical computer, for which a cam mechanism most easily fulfils many of their requirements. At the same time, it will be of value to students of mechanical engineering and to instructors, offering, as it does, a thoroughly up-to-date treatment of dynamics and machine design, using cams as a basis, and representing a significant extension of the usual kinematic approach to cam action.

The author provides a wide and lucid coverage of both the theoretical and practical aspects of the subject. On the practical side, concrete recommendations are made on such topics as mass, acceleration, materials, and the type of cam and follower to be used. Of special interest is a discussion of profile accuracy and errors. Mathematics is kept to a minimum. Bearing in mind the current trend towards high-speed machinery, automation, computers, and servo-mechanisms, there can be no doubt that Professor Rothbart has helped to satisfy in this volume a growing need on the part of machine designers.

Kempe's Engineers Year-Book, 1957. 62nd Edition. Edited by C. E. Prockter, M.I.E.E., M.I.Mech.E., under the direction of B. W. Pendred, M.I.Mech.E., M.I.S.I. 2740 pp., Publishers: Morgan Brothers (Publishers) Limited, 28 Essex Street, London, W.C.2. Price: 82/6 (two volumes in case).

Covering virtually every branch of engineering and constituting a comprehensive, up-to-date, and authoritative source of information on an exceptionally wide range of subjects, the seventy-nine chapters of this new edition of Kempe's will supply, as always, the answers to innumerable queries. Most chapters have a short bibliography, detailing the standard works on the subject, and an index, with over 17,000 references, is included. Additions have been made to several chapters, and all have been revised, where necessary.

Maintenance of High-Speed Diesel Engines. 4th Edition. By Arthur W. Judge, A.R.C.S., D.I.C., Wh.Sc., A.M.I.Mech.E., A.M.I.A.E. 422 pp., 251 illustrations. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 56/-.

In this new fourth edition, much of the earlier material has been re-written and a considerable number of new illustrations introduced to bring the information in this authoritative work up to date. In addition, the chapters have to some extent been re-arranged, and two new chapters, including one on the subject of engine testing and overhaul, have been added.

As before, much of the information, data, and illustrations has been selected from the practice of the leading manufacturers of engines and equipment, with the requirements of the reader, e.g., diesel engineers, service mechanics, operators, apprentices, and others concerned with the practical aspects of the compression-ignition engine in mind. Although the treatment of the subject is mostly concerned with the automobile type of compression-ignition engine, notably engines fitted to motor cars and to passenger and commerical vehicles, much of the information given is applicable to other types, e.g., stationary, marine, agricultural, locomotive, and tractor types.

LATEST INDUSTRIAL LITERATURE

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2. Hydrogen Content Measurement. This 2-page leaflet describes a new instrument which is now in production and which is designed for the rapid measurement of the hydrogen gas content of aluminium melts. No sampling is required, a direct reading being taken from the melt which makes this lightweight instrument ideal for foundry floor use. The measurement depends upon the diffusion of hydrogen from the melt into nitrogen bubbles which are circulated through the molten metal and then into an electrical gas content determination apparatus. The hydrogen diffuses into the nitrogen until an equilibrum pressure is reached, this being proportional to the gas content of the melt.

3. Tinplate Handbook. Users of tinplate will find this 44-page illustrated book a most useful reference. The material and the method of manufacture are described together with figures for tinplate production up to the end of 1955. The largest section dealing with grades is principally devoted to the key question of the thickness or weight of the tin coating. Units of measurement are defined in the fullest detail, with conversion tables from English and American to metric units. The methods for sampling tinplates for the determination of the grade and quality are set out, together with notes on the question of choosing the most suitable steel for the purpose. Transport, grading and the physical and chemical testing of tinplate are considered, while an extensive glossary includes current terms in English, French, German and Spanish.

4. Photographic Stencils for Duplicating. The equipment and stencil, described in an 8-page illustrated brochure introduce a new methods now being marketed, for the quick reproduction of drawings, type matter, photographs, etc., in quantities which are only limited by the life of the stencil. Two models of a stencil camera are described. One gives simple one-to-one reproduction up to a maximum copy area of $13 \times 8\frac{1}{2}$ in. The alternative model has facilities for enlargement or reduction up to a ratio of 1·8:1, the copy holder accepting matter up to $22\frac{3}{4} \times 29\frac{1}{2}$ in. After exposure the stencil is processed in 7 minutes under darkroom conditions and is then ready for normal duplicating.

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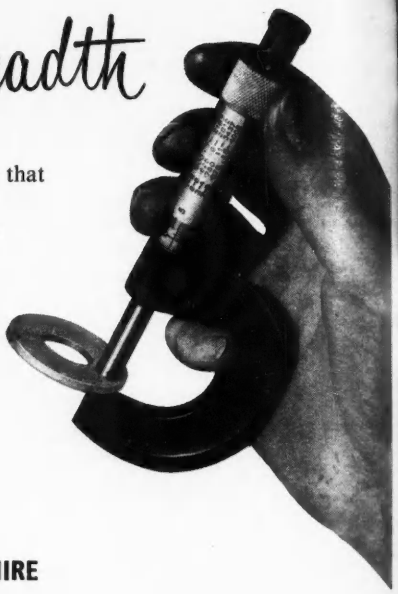

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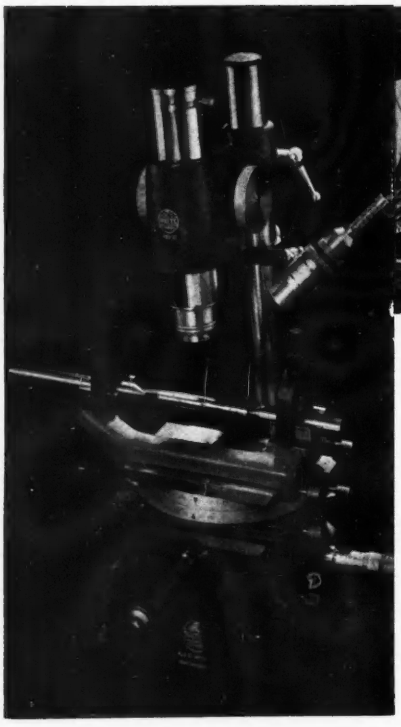

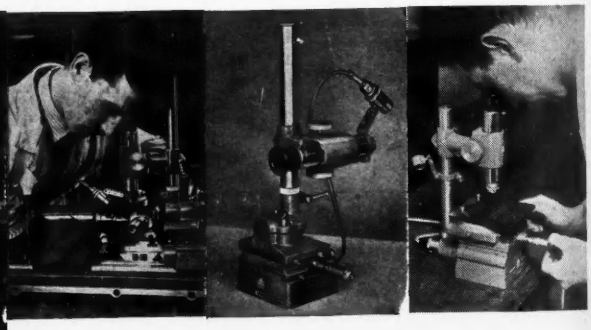

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